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ENGINEERING:

An Illustrated Weekly Journal.

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THE BARCELONA TRACTION, LIGHT AND POWER COMPANY.

By A. HUGUENIN. Director of Messrs. Escher Wyss and Co., Zurich, Switzerland.

THE late Dr. F. S. Pearson organised, four and a half years ago, the Barcelona Traction, Light and Power Company, Ltd., which had purchased practically the whole stock of the Compañia Barcelonesa de Electricidad, and also ten other smaller companies. The object of the new company was to supply electric current at cheap rates to the whole of the Barcelona district, and its programme included the conversion of the existing steam-driven power station at Barcelona into a stand-by station and turning to account the water power available in the rivers Noguera Pallaresa, Segre and Ebro, from the township of Pobla down to the Mediterranean (see map, Fig. 1). For carrying out this programme the company formed the Ebro Irrigation and Power Company, Limited, with offices at Barcelona. A competing French company, the Energia Electrica de Cataluña, started to develop the hydraulic power available south of the Pyrenees on the River Flamisell, at Capdella, at about the same time as the Pearson company commenced operations. The French company had first built a steam-driven power station at Baddalona, a short distance north of Barcelona and on the sea coast. There is also a third company, a Spanish one, the Sociedad Catalana de Gaz y Electricidad, which provides the city of Barcelona and its suburbs with gas, and to a limited extent, also with current, the latter being generated, so far, in a steam-driven plant in Barcelona.

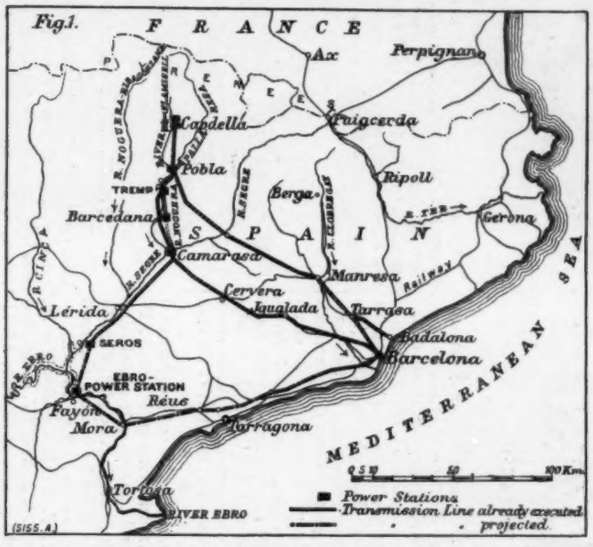

FIG. 1. MAP SHOWING THE COMPANY'S HYDRAULIC POWER STATIONS AND HIGH-TENSION MAINS.

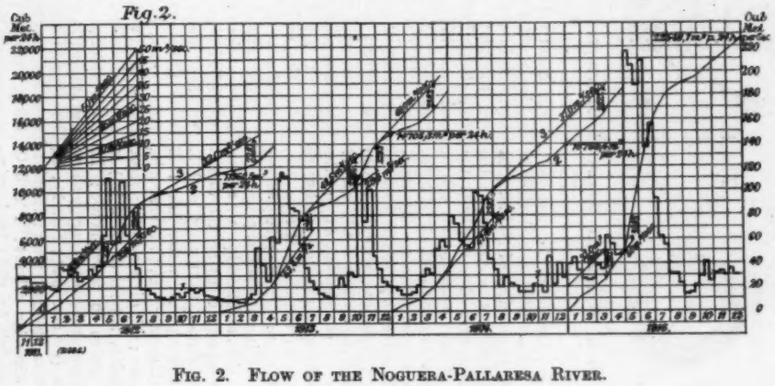

FIG. 2. FLOW OF THE NOGUERA-PALLARESA RIVER.

The hydraulic power development of the Pearson company may be divided into three sections. Work was commenced at Seros, where the power available is about 60,000 h.p., developed under a head of about 50 m. (164 ft.), utilising the river Segre from Lerida downwards for a distance of about 30 km. (18.7 miles). Operations started in December, 1912, and current was delivered in Barcelona as early as April, 1914.

The second section, on which the work is now practically completed, comprises a very large reservoir on the River Noguera Pallaresa, formed by a dam 80 m. (262 ft.) high, the head being about 150 m. (492 ft.). There are to be two power stations, of 50,000 h.p. and 60,000 h.p. respectively, the upper one located near Tremp, less than one mile down-stream from the dam, and the second one 10 miles further down-stream.

The third section will turn to account the River Ebro, near Fayon, where a concrete dam of about 420 m. (1,378 ft.) long and 60 m. (197 ft.) high is contemplated. In this section the power station will develop a minimum of 150,000 h.p. per 24 hours, and is to be equipped for a total of 300,000 horse-power.

Messrs. Escher Wyss and Co. supplied for the first section at Seros the whole mechanical equipment for the power-house and all the pressure mains. They supplied the corresponding material for the second section, including the whole equipment of the head sluice gates, with screens, pressure mains and turbines. They further supplied the pressure mains and turbines to the French company for the Capdella power station, there being five turbines of 8,800 h.p. each, under a head of 850 m. 2,788 ft.), and also all the turbines—of 10,000 h.p. each, running under a head of 135 m. (443 ft.)—which are installed by the Spanish company on the River Essera, at Seira, together with the pressure and distributing water mains.

Taking, in the first place, the second section at Tremp, the dam, as we have already stated, is 80 m. (262 ft.) high, and its length at the crest is 203 m. (666 ft.). The dam raises the water of the Noguera Pallaresa to elevation 540, maximum 541, forming a reservoir of about 11 km. (about 7 miles) in length, which extends as far as Pobla (see map, Fig. 1), and provides a volume of 197,386,000 cub. m. (6,909,000,000 cub. ft.). The diagram, Fig. 2, shows the general hydraulic features of the discharge of the Noguera Pallaresa river without the dam and of the discharge regulated by the dam

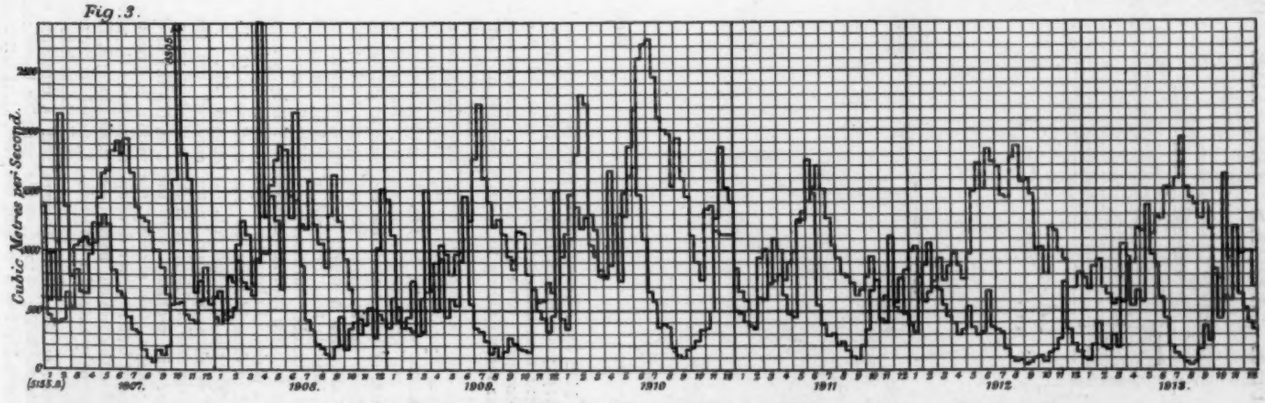

FIG. 3. FLOW OF THE EBRO AT FAYON AND OF THE RHINE AT BASLE.

for the years 1912 to 1915. The curved marked 1 is the discharge per second averaged every ten days, after deduction of the water for irrigation; the curve No. 2 is the natural annual discharge; whilst that of No. 3 is the maximum attainable discharge per second by complete utilisation of the water in the reservoir formed by the dam, namely 197,386,000 cub. m., or 2,282 day-cubic-metres, between levels

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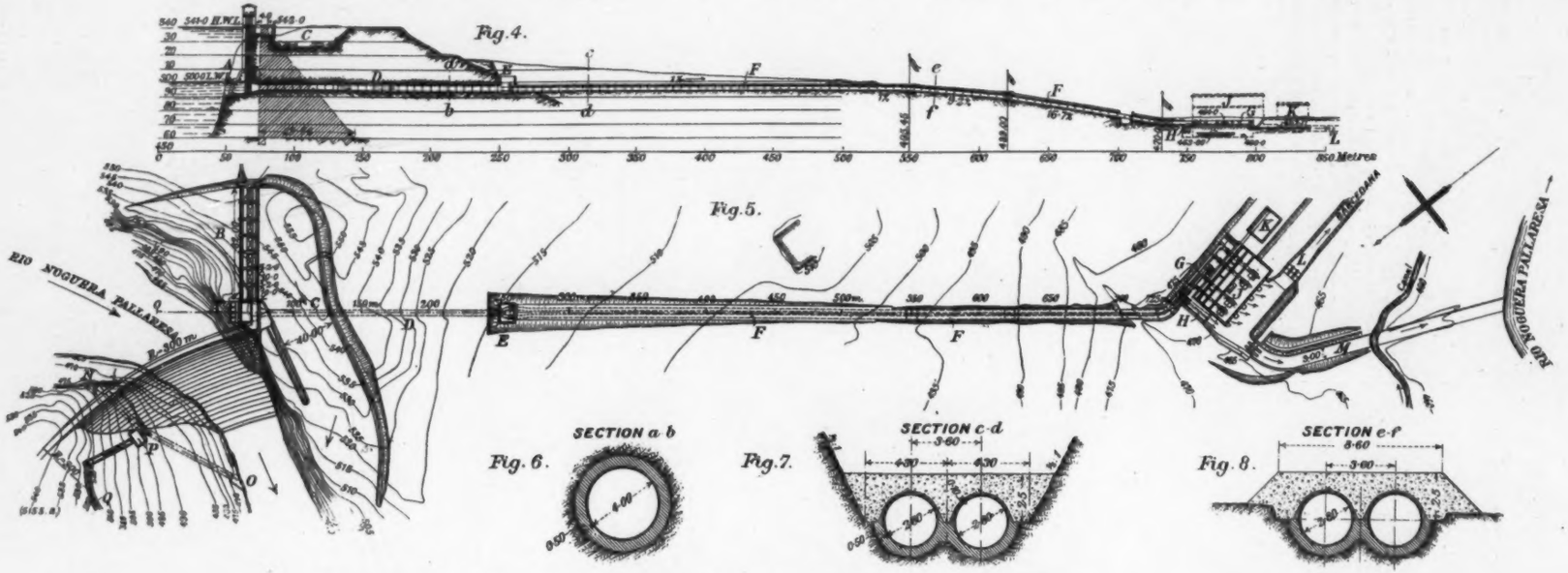

FIGS. 4 TO 8. HYDRAULIC POWER INSTALLATION; TREMP POWER HOUSE.

500 and 540. The year 1912 was a very dry year; 1913 and 1914 were average years, and in 1915 wet weather was very prevalent, there being in the latter year 22,548 day-cubic-metres. (One day-cubic-metre, or 1 cub. m. per second during 24 hours, equals 86,400 cub. m.)

In order that an idea may be obtained of the characteristic flow of the Spanish rivers in the district under consideration, we give, in Fig. 3, in full line, the flow of the Ebro river at about 50 miles from its mouth, and in dotted line the flow of the Rhine at Basle for the same period, 1907 to 1913. Special attention is called to the year 1907, when a considerable flood occurred in the case of the Ebro river in October and November, the discharge amounting to 8,305 cub. m. (290,000 cub. ft.) per second for a period of about ten days, following upon a period of drought when the discharge was only about 80 cub. m. (2,825 cub. ft.) per second. The flood overflows required by the Spanish Government in the case of this river might occasionally have to deal with probably twice the above excessive flood volume, this showing the difficulties which surround water power development in Cataluña, difficulties which have been caused in a great measure by extensive deforestation.

The San Antonio dam, on the River Noguera Pallaresa, which is illustrated in Figs. 4 to 10, on the present and opposite pages, Fig. 9 also showing the Tremp power station, is situated at the narrowest part of the valley, and is embedded on both sides in the rock. It is curved to a radius of 300 m. (984 ft.). Its cross-section has been calculated on the assumption that at the highest water-level the pressure on the whole of the up-stream side will be somewhat greater than that due to the static head.

The dam has been computed as a gravity dam, and has a volume of 270,000 cub. m. (9,500,000 cub. ft.). The load on the foundations, with the water-level at the 540-m. (1,772-ft.) datum, is 8.13 kg. per square centimetre (115 lb. per square inch) on the up-stream side, and 18.65 kg. per square centimetre (265 lb. per square inch) on the down-stream side. With the water-level at 500 m. (1,640 ft.) the pressure is 17.55 kg. per square centimetre (249 lb. per square inch) on the up-stream side, and 2.23 kg. per square centimetre (31 lb. per square inch) on the down-stream side. The references to Figs. 4 and 5, annexed, are the following: A, water inlet; B and C, high-water overflow weir; D, pressure main, 4 m. (13 ft.) in diameter; E, division of pressure main; F, pressure mains, 2.8 m. (9 ft. 2 in.) in diameter; G, water mains to power-house; H, waste pipes; J, Tremp power-house; K repair shop; L, canal to Barcedana (see also map, Fig. 1); M, re-discharge into Noguera Pallaresa river; N, inlet; and O, discharge of diversion culvert; P and Q, pumping house and conduit for right bank irrigation, which latter are illustrated in the view, Fig. 10.

For constructing the dam a complete cement-making plant was put down on the right bank of the river in the immediate neighbourhood of the site, the plant being capable of dealing with a production of 320 tons per 24 hours. The cement used was of a slowly hardening quality. The preliminary work was commenced in the early part of 1913 with the putting down of the cement-making plant and the construction of the diversion culvert marked N O in Fig. 5, to divert the river during the construction of the dam. The excavation of the rock for laying the foundations of the dam was surrounded with many difficulties, owing to the variable nature of the rock formation at the site.

The details of the work carried out are illustrated in the various illustrations given on Plates XXIV to XXVII, Figs. 11 and 12 showing the intake and four head sluice gates in section and plan, Figs. 13 to 15 illustrating the gear for raising the head sluice gates, which are shown in Figs. 16 to 21, on Plates XXIV and XXV, and in the view Fig. 22, annexed. Figs. 23 and 24, Plate XXV, show emergency sluice gates, and Figs. 25 and 26, Plate XXVI, the automatic overflow gates at the overflow weir. The weir is illustrated in course of construction in the view Fig. 27, on Plate XXVII, Fig. 28, on the same Plate, showing the overflow automatic gates on the down-stream side, Fig. 29 illustrating the dam and pump-house and Fig. 30 the screens.

The overflow weir, B and C in Figs. 4 and 5, is designed to deal with the enormous volume of 2,000 cub. m. (70,000 cub. ft.) per second. Seven automatic overflow gates, each 10 m. (32 ft.) broad and 6 m. (19 ft.) high, of a special patent design owned by the Stauwerke Company, Zurich, have

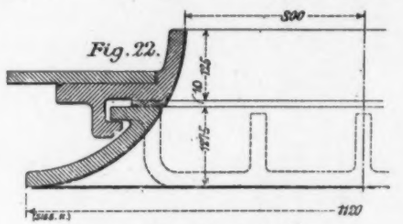

FIG. 22. SLUICE GATE BY-PASS.

been provided in the weir. These are illustrated separately in Figs. 25 and 26, on Plate XXVI. Each gate is balanced by means of two levers having their fulcra at the top of the side masonry piers, as shown in our illustrations. The shape given to the gate itself, combined with the position of the fulcrum and the adjustable length of the counter-weight arm, render it possible to obtain a perfect balancing of the whole system for any flow from nil to the maximum stated above. The maximum

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FIG. 9. DAM ON THE RIVER NOGUERA-PALLARESA AND TREMP POWER HOUSE.

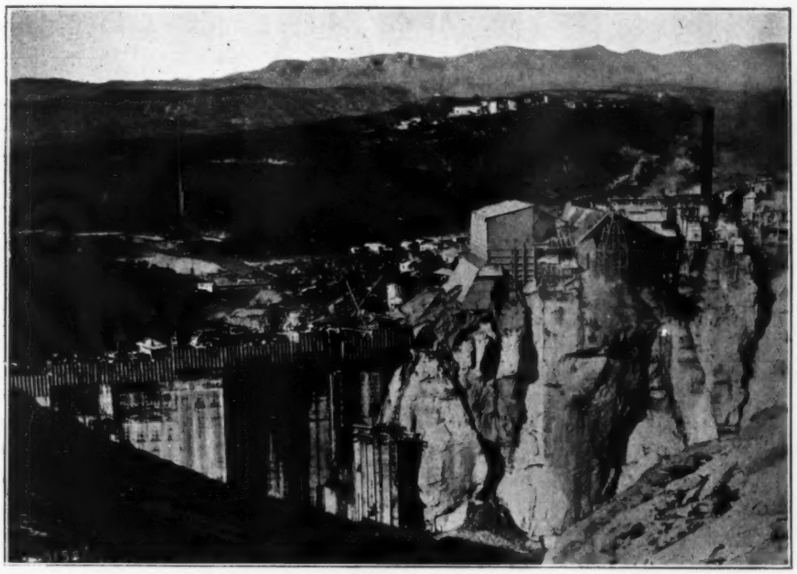

FIG. 10. DAM IN COURSE OF CONSTRUCTION; UP-STREAM SIDE.

permissible variation in the water-level guaranteed by the manufacturers amounts only to 15 cm. (about 6 in.). Automatic gates on this system have been put down and have given excellent results in a large number of instances. The overflow water is carried into the cutting C, Figs. 4 and 5, excavated in the rock on the left-hand bank, and thence discharged into the river, as illustrated in the view, Fig. 29 on Plate XXVII, which also shows the pump-house, marked P, in Fig. 5. The culvert N O, built to divert the river whilst the dam was in course of construction, was ultimately filled up with concrete, starting from the down-stream end.

The Tremp power-house is about 800 m. ($\frac{1}{2}$ mile) below the dam, and the turbines run under a maximum head of 70 m. (229 ft.) and a minimum head of 30 m. (98 ft.). It contains four turbines, which are capable of taking 72 cub. m. (2,540 cub. ft.) per second. The supply is, however, at times far in excess of their demand, which is the reason why the Spanish Government has required the company to provide for the overflow discharge of 2,000 cub. m. per second above-mentioned. Owing to the ground on the down-stream side sloping very gradually, the pressure mains have a very small gradient. They have to carry a maximum volume of water of 60 cub. m. (2,120 cub. ft.) per second, so that their cross-section is a comparatively large one. The first portion of the mains is laid in a tunnel blasted out of the solid rock on the left-hand side of the dam. The first portion in question is built up of riveted pipe lengths, 4 m. (13 ft.) in diameter (see Fig. 6), securely fixed to the outside concrete, whilst the lower portion, from E, in Figs. 4 and 5, consists of two parallel pipes, 2.8 m. (9 ft. 2 in.) in diameter each (see Figs. 7 and 8), laid in a cutting in the rock and embedded in concrete. The method followed does away with the necessity of providing expansion joints at the three bends, which is a decided advantage, considering the large diameter of the pipes. The concrete mass covering the pipes being itself covered with earth about a yard in depth, expansion and contraction due to variations in the outside temperature are very small in extent.

The head gates and screens for such a large quantity of water and so great a pressure as 40 m. (131 ft.) had to be very carefully thought out. They were designed and built by Messrs. Escher Wyss and Co. There are four inlets, 5.5 m. (18 ft.) high and 1.6 m. (5 ft. 3 in.) wide (Figs. 11 and 12, on Plate XXIV), each of which can be closed by a sluice gate. It was considered necessary to provide screens, and in order to so arrange these that they may be cleaned at any time, two movable screens, each 8 m. (26 ft.) high, 2 m. (6 ft. 6 in.) wide, with a clearance of 30 mm. ($1\frac{3}{16}$ in.) between the bars, have been fitted, fully equipped with lifting rods to raise them out of the water above the highest water-level. It was, further, deemed advisable to provide for rough screening, and for this purpose screens having a clearance of 100 mm. between the bars (shown in the view Fig. 30, on Plate XXVII) have been fitted also. All the gear for operating the sluice gates and lifting the screens has been arranged in the small house built directly above the sluice gates, and shown in Figs. 13 to 15, on Plate XXIV. The gates are illustrated in Figs. 16 and 17, on Plate XXIV, and in Figs. 18 to 21, on Plate XXV.

The designing of the gear for operating the sluice gates was somewhat complicated. The lifting bars had to be made as strong and as light as possible, to facilitate lifting a gate out of the water whilst the plant was in operation, and hence the bars were divided into lengths of 6 m. (19 ft. 8 in.) each, formed of wrought-iron pipes, 500 mm. (19 in.) in diameter. The house containing the operating gear was designed to allow of taking the lifting bars to pieces should occasion arise. Each gate is provided with by-passes, shown in Figs. 18 to 21, and in detail in Fig. 22, on page 294. These by-passes are open both on lifting and on lowering the gates. The whole design ensures the maximum strength with a minimum weight, and offers the further advantage that each 500 mm. tubular lifting bar acts at the same time as a vent for the pressure main. The gates can be operated both by power and by hand; the latter means takes much time, but its provision is useful in case of an emergency.

Having regard to the great importance which attaches to these head gates, it was decided to provide at E (Figs. 4 and 5) a butterfly valve, 2.8 m. in diameter, in each of the two branch mains; these valves are operated hydraulically, and by hand when the water-level in the reservoir is low. Further, in order to provide for the untoward circumstance that one of the four sluice gates could not be closed through any cause, it being necessary to cut off the water supply rapidly—a condition which is otherwise required for maintenance and repair—the inlet shafts have been made with grooves for taking special built-up emergency gates, shown in Figs. 23 and 24, on Plate XXV, which allow of closing the pressure main even when the reservoir is at its highest level. These emergency gates are operated by a travelling winch electrically driven.

(To be continued.)

CRITICAL LOADS FOR LONG TAPERING STRUTS.

By ARTHUR MORLEY.

I. *Introductory.*—The critical axial load for a straight strut, so long that it fails entirely by flexure, is found by solving the equation

$$EI\frac{d^2y}{dx^2} = M \quad . \quad . \quad . \quad (1)$$

where y is the deflection of the centre line of the strut from its original position at a distance x from an origin chosen in the centre line, M the bending moment produced by the axial load, E Young's modulus for the material, and I the moment of

inertia of the cross-section about an axis perpendicular to the plane of bending.

Taking the simplest form of end conditions in Fig. 1, one end O being fixed and the other end A being entirely free, the bending moment at Q is

$$M = EI\frac{d^2y}{dx^2} = P(y_A - y) \quad . \quad . \quad . \quad (2)$$

In an article in ENGINEERING* the writer has shown how, when I is not constant, but a function of x, P may be found by assuming a reasonable form of y as a function of x. Briefly the method is to substitute for y and integrate the equation (2) twice with due regard to the end conditions, and so obtain a new value for y in terms of P, and by substituting the new value y at, say, $x = l$, to solve the resulting equation for P. A new and, in general, more correct value of y as a function of x is obtained, and repetitions of the process (if necessary) yield successive approximations to the true value of P, which is approached as a limiting value. With a shrewd choice of the original form of y, not more

Fig. 2.

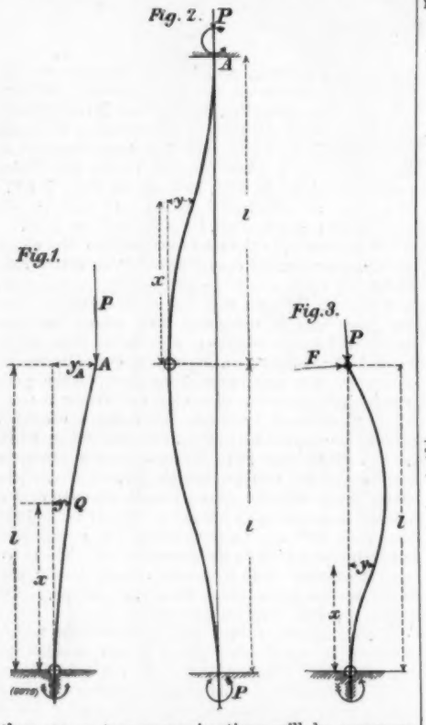

Fig. 1.

Fig. 3.

than one or two approximations will be necessary to yield a substantially correct result, and the correctness may be judged by the degree of change in successive values of either P or y.

In a later article† Messrs. Bairstow and Stedman, referring to this method, wrote, "The application of the method, however, appears to be somewhat difficult if the variation of the section of the columns does not take one or other of certain specified forms," and then proceeded to describe what they considered a more generally applicable method.

The writer does not agree with their view, and proposes to indicate how the method he has described can very easily be applied to the most general cases, including the numerical example with which Messrs. Bairstow and Stedman illustrated their article. He proposes at the same time to briefly describe an alternative method to that of Messrs. Bairstow and Stedman and to show that their numerical results are erroneous and why they are so.

II. *Illustrative Example.*—The spruce strut used by Messrs. Bairstow and Stedman to illustrate their article was symmetrical about a central plane perpendicular to the longitudinal axis, and was hinged at each (thin) end. The critical load for such a strut is the same as that for a strut of half the length entirely free at the thin end and firmly fixed at the other (thick) end. This strut is defined by the following values of I, where x is measured from an origin taken at the fixed end.

x/l	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
I	0.400	0.395	0.385	0.365	0.340	0.310	0.275	0.235	0.190	0.130	0.060

$E = 1{,}500$ lb. per square inch and $l = 35$ in.

A convenient curve to assume for y in Fig. 1 is

$$y = \frac{x^2}{l^2}y_A \quad . \quad . \quad . \quad . \quad . \quad (3)$$

so that,

$$\left.\begin{aligned} M = P(y_A - y) &= P\left(1 - \frac{x^2}{l^2}\right)y_A \\ \text{or} \quad M/P &= \left(1 - \frac{x^2}{l^2}\right)y_A \end{aligned}\right\} \quad . \quad (4)$$

As y is everywhere proportional to y_A, the value chosen for y_A is immaterial, and in approximation may conveniently be taken as unity.

The table has been written in full for the sake of clearness and checking the work, but columns (6) and (8) are, of course, not necessary, being obtained (after the first increments) by moving the decimal point in the respective preceding column values.

The increments δy are, of course, properly calculated from the values of i midway between the ends of the increments terminated by sections at $0.1\,l$, $0.2\,l$, ... $0.3\,l$, $0.9\,l$, $1.0\,l$ from the fixed end, *i.e.*, from values of i at $0.05\,l$, $0.15\,l$, $0.25\,l$, &c., from 0.

TABLE I.

(1) $\frac{x}{l}$	(2) $\frac{y}{y_A}$	(3) $\frac{M}{P}$	(4) I	(5) $\frac{M}{I} \div P$	(6) $\frac{E}{Pl} \cdot \delta i$	(7) $\frac{E}{Pl^2} \cdot i$	(8) $\delta y \times \frac{E}{Pl^2}$	(9) $y \times \frac{E}{Pl^2}$	(2A) $\frac{y}{y_A}$
0	0	1.00	0.4	2.500	—	—	0	0	0
(0.025)		(0.9994)	(0.3988)	(2.506)					
0.05	—	—	0.3975	—	0.1253	0.1253	—	—	—
0.1	0.01	0.99	0.395	2.517	—	—	0.0125	0.0125	0.0104
0.15	—	—	—	—	0.2517	0.3770	—	—	—
0.20	0.04	0.96	0.385	2.494	—	—	0.0377	0.0502	0.0416
0.25	—	—	—	—	0.2494	0.6264	—	—	—
0.30	0.90	0.91	0.365	2.493	—	—	0.0626	0.1128	0.0936
0.35	—	—	—	—	0.2493	0.8757	—	—	—
0.40	0.16	0.84	0.340	2.470	—	—	0.0876	0.2004	0.1662
0.45	—	—	—	0.2470	1.1227	—	—	—	—
0.50	0.25	0.75	0.310	2.420	—	—	0.1123	0.3127	0.2595
0.55	—	—	—	—	0.2420	1.3647	—	—	—
0.60	0.36	0.64	0.275	2.328	—	—	0.1365	0.4492	0.3727
0.65	—	—	—	—	0.2328	1.5975	—	—	—
0.70	0.49	0.51	0.235	2.170	—	—	0.1598	0.6090	0.5050
0.75	—	—	—	—	0.2170	1.8145	—	—	—
0.80	0.64	0.36	0.190	1.898	—	—	0.1815	0.7905	0.6555
0.85	—	—	—	—	0.1898	2.0043	—	—	—
0.90	0.81	0.19	0.130	1.462	—	—	0.2004	0.9909	0.8217
0.95	—	—	—	—	0.1462	2.1505	—	—	—
1.00	1.00	0.00	0.060	0.00	—	—	0.2151	1.2060	1.0000
Totals to check					2.1505		1.2060		

TABLE IA.

(1A) $\frac{x}{l}$	(3A) $\frac{M}{P}$	(5A) $\frac{M}{I} \div P$	(6A) $\delta i \times \frac{E}{Pl}$	(7A) $i \times \frac{E}{Pl}$	(8A) $\delta y \times \frac{E}{Pl^2}$	(9A) $y \times \frac{E}{Pl^2}$	(2B) $\frac{y}{y_A}$
0.00	1.0000	2.500	—	—	0.0000	0.0000	0.0000
(0.025)		(2.506)					
0.05	—	—	0.1253	0.1253	—	—	—
0.1	0.9896	2.505	—	—	0.0125	0.0125	0.0104
0.15	—	—	0.2505	0.3758	—	—	—
0.2	0.9584	2.489	—	—	0.0376	0.0501	0.0419
0.25	—	—	0.2489	0.6247	—	—	—
0.3	0.9064	2.483	—	—	0.0625	0.1126	0.0943
0.35	—	—	0.2483	0.8730	—	—	—
0.4	0.8338	2.450	—	—	0.0873	0.1999	0.1674
0.45	—	—	0.2450	1.1180	—	—	—
0.5	0.7405	2.389	—	—	0.1118	0.3117	0.2609
0.55	—	—	0.2389	1.3569	—	—	—
0.6	0.6273	2.282	—	—	0.1357	0.4474	0.3747
0.65	—	—	0.2282	1.5851	—	—	—
0.7	0.4950	2.106	—	—	0.1585	0.6059	0.5066
0.75	—	—	0.2106	1.7957	—	—	—
0.8	0.3445	1.813	—	—	0.1796	0.7855	0.6579
0.85	—	—	0.1813	1.9770	—	—	—
0.9	0.1783	1.372	—	—	0.1977	0.9832	0.8235
0.95	—	—	0.1372	2.1142	—	—	—
1.0	0.0000	0.000	—	—	0.2114	1.1946	1.0000
Totals to check	—	—	2.1142	—	1.1946	—	—

For approximate integration by tabulation the relations to be used with equal increments of length $\delta x = 0.1\,l$ are

$$\left.\begin{aligned} \delta i = \frac{M}{EI}\cdot\delta x &= \frac{1}{10}\cdot\frac{l}{E}\cdot\frac{M}{I} = \frac{1}{10}\cdot\frac{Pl}{E}\cdot\frac{y_A - y}{I} \\ \text{or} \quad \frac{E}{Pl}\cdot\delta i &= \frac{1}{10}\,\frac{y_A - y}{I} \end{aligned}\right\} \quad (5)$$

$$\left.\begin{aligned} \delta y = i\,.\,\delta x &= \frac{1}{10}\,.\,l\,.\,i = \frac{l}{10}\sum_0^x(\delta i) \\ \text{or} \quad \frac{E}{Pl^2}\cdot\delta y &= \frac{1}{10}\sum_0^x\left(\frac{1}{10}\cdot\frac{y_A - y}{I}\right) \end{aligned}\right\} \quad (6)$$

As the values of I are given exactly at $x = 0.1\,l$, $x = 0.2\,l$, &c., the appropriate lengths for computing the increments δi from (5) will be from $x = 0.05\,l$ to $x = 0.15\,l$, $x = 0.15\,l$ to $x = 0.25\,l$, &c., so that the values of M/I in (5) fall in the middle points of the increments of length and give a fair average value for the length δx. After the values of M/I are written down it is easy to estimate very nearly the value of M/I at $x = 0.025\,l$ for calculating the special value of δi from $x = 0$ to $x = 0.05\,l$. The values of M/P, M/I P, E . δi/P l, &c., are shown in Table I, where $y_A = 1$.

Table I shows at the free end ($x = l$) where $y = 1$

$$\frac{E\,y_A}{P\,l^2} = 1.206 \text{ or } P = \frac{E}{1.206\,l^2} = \frac{1{,}500{,}000}{1.206 \times 1225} = 1015 \text{ lb.} \quad (7)$$

The process is repeated in Table IA, and to facilitate comparison of results y_A is again reduced to unity by dividing column (9) by 1.206, giving column (2A) in Table I.

Table IA yields the value

$$P = \frac{1{,}500{,}000}{1.1946 \times 1225} = 1025 \text{ lb.} \quad . \quad . \quad (8)$$

while Table IB gives

$$P = \frac{1{,}500{,}000}{1{,}193 \times 1225} = 1026.4 \text{ lb.} \quad . \quad . \quad (9)$$

The limit is evidently nearly reached, as shown by the small change in y at $x = l$ (and, therefore, of

* April 24, 1914.

† "Critical Loads for Long Struts of Varying Section," ENGINEERING, October 2, 1914.

TABLE Ib.

(1B) $\frac{x}{l}$	(3B) $\frac{M}{P}$	(5B) $\frac{M}{I} \div P$	(6B) $\delta i \times \frac{E}{Pl}$	(7B) $i \times \frac{E}{Pl}$	(8B) $\delta y \times \frac{E}{Pl^2}$	(9B) $y \times \frac{E}{Pl^2}$
0.00	1.0000	2.500	—	—	0.0000	0.0000
(0.025)		(2.506)				
0.05	—	—	0.1253	0.1253	—	—
0.1	0.9896	2.505	—	—	0.0125	0.0125
0.15	—	—	0.2505	0.3758	—	—
0.2	0.9581	2.488	—	—	0.0376	0.0501
0.25	—	—	0.2488	0.6246	—	—
0.3	0.9057	2.481	—	—	0.0625	0.1126
0.35	—	—	0.2481	0.8727	—	—
0.4	0.8326	2.446	—	—	0.0873	0.1999
0.45	—	—	0.2446	1.1173	—	—
0.5	0.7391	2.384	—	—	0.1117	0.3116
0.55	—	—	0.2384	1.3557	—	—
0.6	0.6253	2.274	—	—	0.1356	0.4472
0.65	—	—	0.2274	1.5831	—	—
0.7	0.4934	2.100	—	—	0.1583	0.6055
0.75	—	—	0.2100	1.7931	—	—
0.8	0.3421	1.801	—	—	0.1793	0.7848
0.85	—	—	0.1801	1.9732	—	—
0.9	0.1765	1.358	—	—	0.1973	0.9821
0.95	—	—	0.1358	2.1090	—	—
1.0	0.0000	0.000	—	—	0.2109	1.1930
Totals to check ..			2.1090		1.1930	

TABLE II.

(1) $\frac{x}{l}$	(2) $y_A - y$	(3) I	(4) $\frac{M}{I}$	(5) $\delta i \times \frac{E}{l}$	(6) $i \times \frac{E}{l}$	(7) $\delta y \times \frac{E}{l^2}$	(8) $y \times \frac{E}{l^2}$	(9) y
0.000	1.0000	0.4	2,500	0.0	0.0	0.00	0.00	0.0000
(0.025)		(0.3988)	(2,506)					
0.05	—	—	—	125.3	125.3	—	—	—
0.1	0.9898	0.395	2,506	—	—	12.53	12.53	0.0102
0.15	—	—	—	250.6	375.9	—	—	—
0.2	0.9591	0.385	2,491	—	—	37.59	50.12	0.0409
0.25	—	—	—	249.1	625.0	—	—	—
0.3	0.9080	0.365	2,488	—	—	62.50	112.62	0.0920
0.35	—	—	—	248.8	873.8	—	—	—
0.4	0.8366	0.340	2,461	—	—	87.38	200.00	0.1634
0.45	—	—	—	246.1	1,119.9	—	—	—
0.5	0.7452	0.310	2,403	—	—	111.99	311.99	0.2548
0.55	—	—	—	240.3	1,360.2	—	—	—
0.6	0.6341	0.275	2,306	—	—	136.02	448.01	0.3659
0.65	—	—	—	230.6	1,590.8	—	—	—
0.7	0.5042	0.235	2,146	—	—	159.08	607.09	0.4958
0.75	—	—	—	214.6	1,805.4	—	—	—
0.8	0.3568	0.190	1,878	—	—	180.54	787.63	0.6432
0.85	—	—	—	187.8	1,993.2	—	—	—
0.9	0.1940	0.130	1,493	—	—	199.32	986.95	0.8060
0.95	—	—	—	149.3	2,142.5	—	—	—
1.0	0.0187	0.000	0	—	—	214.25	1,201.10	0.9809

TABLE IIa.

(1) $\frac{x}{l}$	(2) $y_A - y$	(3) I	(4) $\frac{M}{I}$	(5) $\delta i \times \frac{E}{l}$	(6) $i \times \frac{E}{l}$	(7) $\delta y \times \frac{E}{l^2}$	(8) $y \times \frac{E}{l^2}$	(9) y
0.000	1.0000	0.4	—	0.0	0.0	0.00	0.0	0.0000
(0.025)		(0.3988)	2,573					
0.5	—	—	—	128.6	128.6	—	—	—
0.1	0.9895	0.395	2,568	—	—	12.86	12.86	0.0105
0.15	—	—	—	256.8	385.4	—	—	—
0.2	0.9580	0.385	2,551	—	—	38.54	51.40	0.0420
0.25	—	—	—	255.1	640.5	—	—	—
0.3	0.9057	0.365	2,543	—	—	64.05	115.45	0.0943
0.35	—	—	—	254.3	894.5	—	—	—
0.4	0.8326	0.340	2,510	—	—	89.45	204.93	0.1674
0.45	—	—	—	251.0	1,145.8	—	—	—
0.5	0.7391	0.310	2,444	—	—	114.58	319.51	0.2609
0.55	—	—	—	244.4	1,390.2	—	—	—
0.6	0.6255	0.275	2,331	—	—	139.02	458.53	0.3745
0.65	—	—	—	233.1	1,623.3	—	—	—
0.7	0.4930	0.235	2,138	—	—	162.33	620.86	0.5070
0.75	—	—	—	213.8	1,837.1	—	—	—
0.8	0.3429	0.190	1,850	—	—	183.71	804.57	0.6571
0.85	—	—	—	185.0	2,022.1	—	—	—
0.9	0.1778	0.130	1,402	—	—	202.21	1,006.78	0.8222
0.95	—	—	—	140.2	2,164.1	—	—	—
1.0	0.0000	0.000	0	—	—	216.41	1,223.19	0.9989

TABLE III.

x/l	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Actual I ..	0.4	0.395	0.385	0.365	0.340	0.310	0.275	0.235	0.190	0.130	0.060
$0.4\left(1-\frac{x^2}{l^2}\right)$ ..	0.4	0.396	0.384	0.364	0.336	0.300	0.256	0.204	0.144	0.076	0.000
$0.4-0.36\frac{x^2}{l^2}$	0.4	0.3964	0.3856	0.3676	0.3424	0.310	0.2704	0.2236	0.1696	0.1084	0.040

P), and the repetition of column (2B) in column (2c); it may be taken as just below 1,027 lb.

By assuming a less curved form of y, such as

$$y = y\frac{x^2}{2l^2}(3 - x/l) \quad . \quad . \quad . \quad (10)$$

the successive values of P obtained are

1,066 lb., 1,031 lb., 1,027 lb.,

which evidently approach the same limit about 1,026 to 1,027 lb. A second approximate value of P from a curve of the form (3) will in any practical case always give a very close approximation to the true critical load, slightly on the safe side. This method appears to the writer to possess the advantages of directness, simplicity and speed as compared with one dependent upon building up the y curve by trial and error at each calculation of an increment. It reduces to a very simple arithmetical process, which can be carried out without a knowledge of mathematics or accurate plotting, and no preliminary estimate of P is required. It is also applicable to other less common end conditions, such as the case where one end is fixed and the other end hinged, and the case where both ends are fixed.

III. *Alternative Method.*—In the method described by Messrs. Bairstow and Stedman, and in a somewhat similar method about to be described, a preliminary estimate of the critical load is required. This may easily be obtained, and indeed generally with a sufficient accuracy for all practical purposes, by the method previously described by the writer, by writing for I an approximate algebraic function of x. For example, in the preceding numerical case, if we take

$$I = 0.4\,(1 - x^2/l^2) \quad . \quad . \quad . \quad (11)$$

and combine with it the assumption (3) we obtain

$$P = \frac{2 \times E \times 0.4}{1225} = 980 \text{ lb.} \quad . \quad . \quad (12)$$

which was Messrs. Bairstow's result. The relation

$$P = \frac{2\,E\,I_0}{l^2} \quad . \quad . \quad . \quad . \quad (13)$$

is in fact an exact solution, as may be verified by substituting the values (3), (11) and (13) in equation (2). But this strut defined by (11) is weaker than the actual one, as shown by Table III, annexed.

A better approximation, bearing in mind that the section near the fixed end is most important in resisting flexure, would be that corresponding to a parabola giving correct values at $x = 0$, and at $x = 0.5\,l$ (instead of at $x = l$), viz.

$$I = 0.4 - 0.36\frac{x^2}{l^2}$$

Integrating equation (2) with assumption (3) gives as a first approximation on a basis of a rising series of values

$$P = 1{,}010 \text{ lb.}$$

Assuming from these estimates a preliminary load of say 1,000 lb., and taking $y_A = 1$, Table II may be constructed without any assumption as to the form of y. Estimating a value of M/I at $x = 0.025\,l$, we find from the formula (5) the value of δi (which is also i) at $x = 0.05\,l$, and hence from formula (6) the value of δy (which is also y) at $x = 0.1\,l$. A sample calculation for a later part of the table will suffice. After the lines for $x = 0.3\,l$ and $x = 0.35\,l$ are completed, in order to fill up the line for $x = 0.4\,l$. column (7) is first found by dividing the previous entry in column (6) by 10, viz., $873.8 \div 10 = 87.38$. This is next added to 112.62 in column (8), and the entry 200.00 in column (8) is obtained. Dividing the 200.00 by E/l^2 gives 0.1634 in column (9). Subtracting 0.1634 from unity, 0.8366 in column (1) is obtained. Multiplying by 1,000 (*i.e.*, P) and dividing by 0.340 gives 2,461 in column (4). The increment $\delta i \times \frac{E}{l}$ and the total $i \times \frac{E}{l}$ at $x = 0.45\,l$ follow as in Table I.

The final value of y_A is 0.9809 instead of unity, which shows that the trial value of P is too low. Correcting proportionally, $1{,}000 \div 0.9809 = 1{,}020$ lb. But P will be greater than this, for an increase in P produces less than a proportionate increase in the figures in column (9) of Table II. For it reduces the values of $(y_A - y)$, which is a factor of M. Taking therefore a second trial of P as 1,025 lb., Table IIa is obtained. The final value of y_A is here 0.9989, and hence P is rather greater than

$$\frac{1025}{0.9989}, \text{ or over } 1{,}026 \text{ lb.,}$$

which confirms the value obtained from Table Ib.

The two methods of finding the critical load by tabular integration are not very dissimilar; they differ in the choice of which of the two factors of the right-hand side of equation (2) is assumed. In the writer's opinion the method of Table I, *i.e.*, assuming reasonable values of y/y_A, is preferable, as it leads to arithmetically simpler and more direct work. The tabulation can be written down vertically without working horizontally across the columns, and without any trial and correction.

IV. *Degree of Error involved in Tabular Integration.*—Instead of integrating by tabulation it is quite simple to plot values of M/I and find the increments (δi) of i by estimation of areas, and similarly to plot the values of i, and so to estimate the increments δy.

In the tabular method a slight error is in general

USE OF CHROMIC ACID AND HYDROGEN PEROXIDE AS AN ETCHING AGENT.

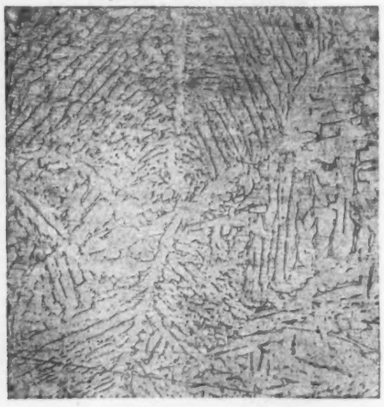

FIG. 1. SPECIMEN ETCHED WITH CHROMIC ACID AND HYDROGEN PEROXIDE. COPPER, 60.74 PER CENT.; ZINC, 39.19 PER CENT. SHOWS α AND β. MAGNIFIED 50 DIAMETERS.

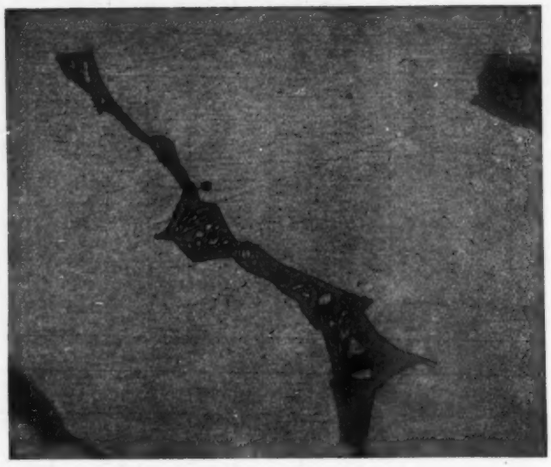

FIG. 2. SPECIMEN LIGHTLY ETCHED WITH CHROMIC ACID AND HYDROGEN PEROXIDE. SHOWS α AND δ. MAGNIFIED 1250 DIAMETERS.

made. Both the M/I and the i curves on a base l are in this particular case convex upwards, and the increments δi and δy were estimated by taking as true mean ordinates the values of M/I and i lying midway between the ends of the increments δx or $0.1\,l$. This leads to an overestimate of y, and, therefore, to an underestimate of P. The degree of error is here quite negligible, as might be shown by estimating it. Perhaps the best way to demonstrate it, however, is to show that it is negligible in applying the tabular methods to cases where the curvatures of the M/I and i curves are actually greater, and the result can also be computed by ordinary (non-tabular) methods of integration. This has been done, with the following results:—

I.	First Assumed Value of y.	Assumed Value of $\frac{P l^2}{E I}$	Successive Coefficients of $\frac{E I_0}{l^2}$ obtained by Tabulation.	Successive Coefficients of $\frac{E I}{l^2} I_0$ obtained in Ordinary Algebraic Integration.	Known Value of the Coefficient.
Constant I_0	$y_A \cdot \frac{x^2}{l^2}$	—	2.395, 2.45	2.400, 2.459	2.467
Constant I_0	$y_A \frac{x^2}{2\,l^2}\left(3 - \frac{x}{l}\right)$	—	2.494, 2.467	2.500, 2.471	2.467
$\left(1 - \frac{x^2}{l^2}\right) I_0$	$y_A \frac{x^2}{l^2}$	—	2 (repeats)	2 (repeats)	2
Constant I_0	—	2.5	2.4705	—	2.467

Other results, where the curvature of the M/I curve is less, have also been worked out, and found to agree very closely indeed with the values obtained by successive algebraic approximations.

The critical load found for the given strut, viz., 1,027 lb., is about 5 per cent. greater than the value (980 lb.) found by Messrs. Bairstow and Stedman. They make an error in principle by taking the values of I at $x = 0.05\,l$, $0.15l$, $0.25\,l$, &c., from the thin end, in finding the values of d^2y/dx^2 at $x = 0.1\,l$, $0.2\,l$, $0.3\,l$, &c., respectively from the relation $d^2y/dx^2 = M/E\,I$. In estimating by tabulation the increments δi, clearly the value of M/EI at the middle of the corresponding increment δx is appropriate. But in estimating i (or δi) by the area under a curve of M/EI, on a base of values of x, the plotted values of M/EI should be those at the corresponding sections and not the values for sections $0.05\,l$ away from the corresponding sections. Messrs. Bairstow and Stedman have used too low a value of I throughout, and have obtained too large a value for the change in slope, which in their case corresponds to too small a value of dy/dx (since they worked from the free end, or rather the hinged end of the strut twice as long, on a diminishing slope). They have in effect calculated the critical load for a more slender strut than the one they specified.

V. *Other End Conditions.*—The method described in Section II of this article is applicable to struts with other types of attachment at the ends, but as these are less important for struts of varying section, it will suffice to mention them briefly.

If the strut of length $2\,l$ is firmly fixed at both ends (Fig. 2), and symmetrical about the central plane of cross-section, taking the origin O at the central section in its deflected position, A being one fixed end,

$$E\,I\,d\,y^2/d\,x^2 = M_A + P\,(y_A - y).$$

A suitable first form of y is found from the equation

$$y = A + B\,\frac{x}{l} + C\left(\frac{x}{l}\right)^2 + D\left(\frac{x}{l}\right)^3 + E\left(\frac{x}{l}\right)^4$$

which, when the constants have been determined from the end conditions (viz., $y = 0$ for $x = 0$, $y = y_A$ for $x = \pm l$, and $d\,y/d\,x = 0$ for $x = \pm l$), becomes

$$y_A - y = y_A\left\{1 + \left(\frac{x}{l}\right)^2\right\}^2$$

Either algebraically or by tabulation there are at first two unknown quantities, M_A and P. In tabulating M/I, δi, $i\,\delta y$ and y the coefficients of M_A and P should be placed in separate columns. Then from the fact that at A, i or $d\,y/d\,x$ is zero, M_A may be found in terms of P, and thus P may be found from the derived value of y_A.

In the case of a strut of length l fixed at one end O and hinged at the other end A (Fig. 3), the equation becomes

$$E\,I\,.\,d^2\,y/d\,x^2 = F\,(l - x) - P\,y$$

where F is a component reaction at the hinge, perpendicular to the axis of the strut, brought into action when buckling begins. The primary form of y here becomes

$$y = 4\,y'\left(\frac{x}{l}\right)^2\left\{2\left(\frac{x}{l}\right)^2 - 5\left(\frac{x}{l}\right) + 3\right\}$$

where y' is the deflection midway between O and A. The critical load may be found by tabulating separately the coefficients of F and P and making $y = 0$ when $x = l$ at A.

With more than one unknown quantity there is an increasing advantage in algebraic working if a suitable approximate function can easily be found for I.

THE USE OF CHROMIC ACID AND HYDROGEN PEROXIDE AS AN ETCHING AGENT.*

By S. W. MILLER (Rochester, N.Y.).

IN the course of recent correspondence Mr. S. W. Miller, of Rochester, N.Y., has communicated to the secretary an account of his method of using a mixture of chromic acid and hydrogen peroxide as a reagent for etching brass and bronze, and has expressed a desire that his experience should be placed at the disposal of those interested in the subject. The substance of Mr. Miller's information has been arranged by Dr. O. F. Hudson in the form of this note.

A dilute solution of chromic acid is used, to which a few drops of hydrogen peroxide are added. The specimen is immersed and kept moving in the solution for a few seconds. It is then removed and washed immediately in running water. Originally Mr. Miller used concentrated chromic acid diluted with an equal bulk of water, and to a small quantity of this solution the hydrogen peroxide was added. Later he found that acid of this strength was too strong, and that he had been using too weak a solution of hydrogen peroxide. Only a few drops, say, six or eight, of chromic acid are necessary, and to this dilute solution a few drops of hydrogen peroxide, which should not be too weak, are added.

The addition of the hydrogen peroxide causes a strong effervescence, and turns the solution of chromic acid a very dark green. If the chromic acid solution is too strong large gas bubbles are evolved, which prevent uniform etching. When, however, the right strength of acid is used, the immersion of the specimen causes a spitting of the liquid, particles of which are projected from the bath on to the sides of the containing vessel.

Mr. Miller states that he finds this reagent equally satisfactory for all brasses and bronzes, and that it is the best of all the reagents for this purpose that he has tried, giving much better results than chromic acid alone. In the case of tin-copper alloys the α is not stained, while the δ remains a light blue. Similarly in the zinc-copper alloys both the α and β are said not to be changed in colour, while in rolled brass the grain boundaries and twin crystals are brought out with great clearness. This reagent has also been found to give good results when used as an etching agent for silver.

Figs. 1 and 2 are typical of the work that can be done with this reagent.

WOODEN AND STEEL RAILWAY CARS.—The insistent demand for the use of lighter and more durable cars, says the *Electric Railway Journal*, New York, has so accustomed the railway men to think only of steel when new cars were under consideration that the tendency is to neglect the possibilities of wood altogether. Perhaps the fact that an emergency exists which makes it practically impossible to get steel plate and, consequently, steel car deliveries within a very long period, may serve to deflect attention to cars of wooden construction. They cannot be built as light as steel cars, but when a company is badly in need of additional rolling-stock there are advantages in reverting for the time being to cars of wooden construction. The steel car will cost less per mile for current to propel it, but for the immediate present a wooden car which could be delivered comparatively very promptly could be earning a substantial revenue during the ten to eighteen months or more that it might be necessary to wait for the steel one.

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* Paper read before the Institute of Metals, Wednesday, September 19, 1917.

A COMPARISON SCREEN FOR BRASS.

A COMPARISON SCREEN FOR BRASS.*

By OWEN WILLIAM ELLIS, M.Sc. (Birmingham).

IN *Metallurgical and Chemical Engineering*, No. 7, vol. xvi, page 378, a "Comparison System for Determining and Standardising the Grain Size of Annealed Brass" is described. The main feature of the apparatus consists of a wooden frame, in which lantern slides, showing microstructures of brasses that have been subjected to definite heat treatment, are fitted in such a way as to enable the operator of the apparatus to estimate, with very fair accuracy, the grain size of a sample of brass of unknown origin, by comparing the magnified image of the sample of brass with the slides of the standard samples, which are of the same magnification.

The method described constitutes a welcome improvement in practice. The apparatus, however, necessitates the use of a wooden framework and the aid of a carpenter, whereas quite an efficient comparison screen can be produced at the cost of only a few pence at a glazier's and a few hours in the laboratory. The main features of the screen about to be described are: (i) a sheet of plain glass of suitable size; (ii) a sheet of ground glass of similar dimensions; and (iii) a packet of transferotype paper (such as that manufactured by the Kodak Company). Prints of the microphotographs of the standard samples are made on the transferotype paper, and are thence, in the approved manner, transferred to the plain glass; the manner that suggests itself to the author as being the most convenient is to cut the prints so as to form zones of sectors of circles, which, when suitably arranged, form a ring whose centre is of clear glass. The number of zones will, of course, be determined by the number of standards required. When the transferred prints are dry, the ground glass may be fitted to the plain glass in such a way that the ground surface of the former supports the prints adhering to the surface of the latter. Between the two sheets of glass a mask may be fitted. The two sheets of glass are finally bound together with *passe-partout*, or lantern-slide binding strip. The final result (except for the black surround) is as shown above.

In practice the image of the sample under examination is projected on to the central screen and direct comparison is made with the standard photographs, which, as already described, form a ring round the central screen. The actual mode of lighting the screen will depend rather on the apparatus apart from the screen than on the screen itself. The author therefore has confined himself entirely to a description of the principle underlying the manufacture of the screen.

LARGE RAILWAY WAGONS.—In a recent issue of *The Railway Age Gazette* a description is given of four cars recently constructed for the Virginia Railway, each of which is intended to carry 120 tons of coal. The cars are 53 ft. 7 in. long over all, the body length being 50 ft. inside and the width inside 9 ft. 8½ in. The maximum height above rail-level is 11 ft. 1½ in. The body is supported on two six-wheel bogies. The wheels are 33 in. over treads and the axles have 6-in. by 11-in. journals. The total weight of the car empty is 73,900 lb. The car is built entirely of steel, the minimum plate thickness used being ¼ in.

* Note read before the Institute of Metals, Wednesday, September 19, 1917.

THE BRIQUETTING OF IRON ORES.

*Notes on the Present Knowledge and Practice in regard to the Briquetting of Iron Ores.**

By GUY BARRETT (Ebbw Vale) and T. B. ROGERSON, (Glasgow).

EARLY this year the Iron and Steel Institute Committee for Ores, Fuel and Refractories appointed Messrs. Frederick Mills and W. Thorneycroft to inquire into the present knowledge and practice in regard to the briquetting of iron ores, and these gentlemen requested the present authors to prepare a *résumé* of the available information on the subject. This they undertook to do, and the following report represents a summary of the knowledge gained in their own experience, together with that communicated from many sources and collected from various publications.

It is not suggested that anything strikingly original or hitherto unknown will be disclosed, the intention is rather to bring together, for the consideration of the members of this Institute, such information as the authors have regarding a subject of great and rapidly increasing importance to this country.

Apart from desirability, on economical grounds alone, of using to a greater extent the many mechanically fine ores which have hitherto found little favour with blast-furnacemen, it cannot be doubted that there is every indication that the proportion of lump ore obtainable is at least not likely to increase; and the recent tendency to adopt higher blast pressures, larger furnaces, and faster driving at the blast-furnaces in this country has, although the limits common in the United States of America have not generally been attained, already reached the point at which the difficulties when using fine ores under these conditions, and the consequent loss of iron in the form of flue-dust, can no longer be ignored.

The present movement towards the increased use of native ores will probably accentuate these difficulties where the ore requires calcination before it is suitable for the blast-furnace, for in the process of calcination a by no means negligible proportion of fines is nearly always made, and as these fines are sometimes the richest part of the ore, the question of briquetting these should be considered. The increased production of sulphuric acid brought about by the war will also bring into the market a quantity of material which would be vastly improved by some briquetting or sintering treatment.

A reduction in the dusty fines in the blast-furnace burden, and the substitution of an easier working material, will bring in its train more regular furnace operation. It will lower the necessary margin of surplus heat required in the furnace for emergencies, and will diminish the iron losses in the form of flue-dust. If these desiderata can be realised, improvements in the iron yield, coke consumption, and a lower pig-iron cost will follow, and for these reasons we have been asked to gather information on this important subject.

A complete report on the present knowledge regarding the briquetting of iron ores in all its aspects would be a very voluminous document, and in the following notes it is proposed to deal only briefly with the leading processes known to be in commercial operation, and to give references indicating where articles dealing fully with these and other processes, specifications and machines may be found. In the conditions prevailing to-day prices vary from week to week, and therefore all prices and costs in this report are based on pre-war conditions, excepting where the contrary is stated. For the purpose of this report the term "briquetting" has been held to include all processes having for their object the conversion of iron ore in a finely divided mechanical condition into a more or less lumpy product suitable for smelting in the blast-furnace.

According to White, Schwarz, Hansell, and other writers who have dealt with this subject, the product of any process should so far as possible fulfil the following conditions: It must not break into dust when dropped on a hard surface from a height of at least 10 ft. It must resist a temperature of about 900 deg. to 1,000 deg. C. without disintegrating. It must resist the effects of the weather for a reasonable time. It must resist the action of such steam as is found in the top of a blast-furnace. It must be porous, to facilitate the penetration of the carbon monoxide of the furnace gas. The binder, if any is used, must contain no objectionable constituent, and the quantity must not seriously affect the iron content of the furnace charge, including both the ore and limestone. The cost of production must not exceed the difference between the cost of the raw material and the value of the improved product.

In general, the processes in use to-day may be divided into the following classes:—

1. Those in which the ore is submitted in suitable moulds to pressure high enough to cause mechanical cohesion.

2. Those in which the ore is pressed, with or without the addition of a binding agent, and subsequently heated by more or less direct firing to the temperature of incipient fusion or vitrifaction.

3. Those in which the ore is mixed with a binder, pressed in moulds, and hardened in air, steam or gas.

4. Those in which the ore is heated, without pressing, to the temperature of incipient fusion or vitrifaction.

Of the first class probably the best known and most widely used is the Ronay process.

Fine ores and flue-dust, as well as such diverse materials as cast-iron and steel borings, salt, coal and sawdust, have all been satisfactorily briquetted simply by the application of mechanical pressure on this system, the mechanical installation for which consists of a low-pressure hydraulic pump, the necessary accumulators and suitable pressure intensifiers, pressure distribution and variation devices, and the hydraulic briquetting press. For the treatment of ores containing moisture a drying drum is recommended to extract all the moisture from the ore.

Great importance is attached to the complete driving out of all the air contained in the ore, and this is effected by applying the pressure slowly and in two separate stages. There is no doubt that this is a most important point in all processes employing even such a relatively moderate pressure as 3 tons per square inch on the briquette, and it is certain that many failures to produce a satisfactory briquette have been due to the neglect of this precaution. Even when this has been achieved, however, it has been found that the very heavy pressures used—6 tons, and even up to nearly 14 tons per square inch on the briquette—will not ensure good briquettes with all classes of ore. Mr. J. G. West* refers to experiments in which flue-dust briquettes were made under a pressure of about 11 tons per square inch, at which point distortion of the cast-iron moulds resulted, but the briquettes were friable and broke if subjected to comparatively slight shocks.

In a report which has come under our notice it is estimated that the cost of briquetting on a press making from 70 tons to 120 tons per day of 20 hours, the rate depending on the density of the material, would be from 8*d.* to 1*s.* per ton for flue-dust or ore which required no drying, and 1*s.* 3*d.* to 1*s.* 9*d.* per ton for ore requiring heat treatment.

A few years ago a plant to make 30,000 tons of ore briquettes per annum was estimated to produce briquettes at 1*s.* 10*d.* per ton, including interest and depreciation, and a plant to produce 50,000 tons was estimated to do so with a working cost of 1*s.* 3*d.* per ton of briquettes. In 1913, A. Weiskopf,† referring to this process, gave the estimated cost, according to the figures furnished by the constructing company, for a plant to produce 30,000 tons of flue-dust briquettes per annum as 6,000*l.*, and the cost of the product, when allowing 15 per cent. depreciation on the machinery and 10 per cent. on the buildings, is given as approximately 1*s.* 8*d.* per ton.

It is very doubtful if the costs given above could be realised on a commercial plant. The machinery is expensive, and the power consumption in actual practice forms a heavy item in the cost, and unless the material worked requires no preliminary or subsequent treatment, it seems unlikely that the process can compete with other processes available, particularly as the necessarily heavy press works relatively slowly and needs at least as much labour as other faster-running machines.

In connection with the preparation of the Mayari ores of Cuba the Mashek process was tried,‡ the plant for which consists of a pair of rolls whose surfaces are provided with corrugations running parallel with their axes. They are held together by powerful springs which exert pressure as the ore is fed into the rolls. The product consists of small cylindrical sticks of compressed ore. They did not stand weathering, and the process was found to be expensive to work.

A few years ago an attempt was made at a works in the North of England to produce ore briquettes by pressure only, and without the addition of a binder. A machine designed to give a pressure of 6 tons per square inch was used, but the result was not satisfactory, and it

* Paper read before the Iron and Steel Institute, Thursday, September 20, 1917.

* *Iron Age*, 1912, vol. xc, page 955.
† *Stahl und Eisen*, 1913, vol. xxxiii, page 276.
‡ *Iron Trade Review*, 1914, vol. lv, page 1215.

was not found possible to produce a suitable briquette without heat treatment.

It may be of interest to note that the particular ore used, an hydrated hematite, is one which offers peculiar difficulties from the briquetting point of view, from the fact that if it has been exposed to the weather it may contain as much as 12 per cent., or even 15 per cent., of water and still be apparently dry and almost dusty before pressing, but under pressure the moisture is squeezed out and assumes the form of a somewhat tenacious mud, which clogs the machine and hinders the work considerably.

So far as we are aware, no process of ore briquetting depending on pressure only has found very wide application. It is hardly likely that this method will prove satisfactory in dealing with ores containing combined water or showing appreciable loss on calcination, because the loss on calcination is represented by water or gases which are liberated by the application of heat alone; and as briquettes made in this way are comparatively dense, the gases freed in the interior of the briquette when the temperature rises find no ready outlet and must tend to burst it into dust again. This would probably occur quite high in the blast-furnace, in which case the benefit of briquetting would be lost.

Of the processes in which the ore is pressed into moulds, with or without the addition of a binder, and subsequently burnt, the following are some which have come under our notice.

Probably the simplest is that worked, at any rate until recently if not still, at a works in the North of England, where blue billy and lime were ground together in a pan until plastic. The mixture was then spread out on a heated floor, and immediately rolled into a sort of a cake by means of a roller resembling a garden roller. It was allowed to remain on the floor until quite dry and then charged into the furnaces. The cost of such a process would naturally be low, but the product would hardly stand much handling without producing a very large proportion of fines.

An improvement on this method is in operation at an ironworks in Scotland, where blue billy is mixed with clayey ore as a binder and then ground in a pan to a slurry. The mixture is dumped into nests of moulds laid on a steam-heated floor. The moulds are lifted off as soon as drying has proceeded far enough to permit this, and the bricks are left to dry until they are hard enough to be stacked and burnt in hand-fired kilns. The loss in this particular case is whatever moisture the fine ore contained before manipulation, and the total cost of manufacture is about 8*s.* 6*d.* per ton at the present time. The system is easily worked and requires no expensive machinery. The heat for the drying floor can be obtained from the exhaust of any suitable steam-engine, and the product is reasonably satisfactory though certainly expensive.

At another works fine ore is tempered in grinding pans with water and then fed into Yeadon type briquetting machines. The briquettes are transferred from the machines to flat trolleys, on which they are passed through drying tunnels about 130 ft. long, 9 ft. wide, and 6 ft. high, which are heated by the waste gases from the kilns. The kilns are ordinary chamber kilns heated with blast-furnace gas. The briquettes are heated to the temperature of incipient fusion and are a reasonably good product, and the cost is said to be low. This plant was very fully described by Dr. Henry Louis* in 1905.

A process in operation in Staffordshire, in 1910, was then making very good briquettes from the accumulation of fine ore left after the repeated clamping of Staffordshire mine on the same ground for some considerable time. The process had no outstanding features to distinguish it from that last described, except that no separate preliminary dryer was used. The fines were tempered first in an edge-runner pan. They were then carried by a double worm mixer conveyor to a mixing pan, and afterwards pressed in a horizontal rotating table press of substantial construction. The briquettes were burnt in Staffordshire kilns, and a fuel consumption of 1.02 cwts. per ton of briquettes was claimed when using slack at 4*s.* per ton, which equals about 4½*d.* per ton of briquettes.

The plant was steam-driven from its own boilers and had an output of 65 tons per day, and a total cost of 3*s.* 11*d.* per ton of briquettes was claimed, taking the cost of ore as 2*s.* at the foot of the hoist which delivered it to the pan. The total labour employed was five boys and 14 men, but the wages were very low, varying from 2½*d.* to 6*d.* per hour, and worked out at 1*s.* 6*d.* per ton of briquettes. A complete installation to give an output of 30,000 tons per annum was estimated to cost 4,000*l.* in 1910.

The Gröndal process,† which has been very widely adopted, is probably able to treat almost any ore which can be pressed into a briquette hard enough to stand being transferred by hand from the press to the table of the kiln car. It gives a very satisfactory product, and appears to have the widest range of suitability of any process falling within the class under consideration. It needs less manual labour than any of those already described, and the method of kiln-firing gives that control of the burning which is so highly important for the manufacture of briquettes of good quality from various and variable ores. Trouble has been experienced, however, when attempts have been made to briquette a mixture containing more than 25 per cent. of flue-dust high in carbon.

Briefly, the process consists of pressing the suitably tempered material at a comparatively low pressure and then passing the briquettes through a gas-fired tunnel kiln. The fuel consumption appears to be from 7½ per cent. to 10 per cent. of the weight of the product. It is said to be only 5 per cent. in certain cases. The cost of a plant capable of producing 1,000 tons per 24 hours was estimated at 100,000*l.* in 1909, and the cost per ton of briquettes, including interest and depreciation, was estimated at 3*s.* 2.77*d.*, with coal at 12*s.* per ton and labour at from 4*s.* to 7*s.* per day, but this cost does not appear to have been realised in recent installations in America.

The cost varies greatly, according to the conditions and material treated, as the following examples will show:

Weiskopf* gives the cost as 4*s.* 7*d.* per ton, allowing 10 per cent. for depreciation, taking coal at 22*s.* and labour at about 3*s.* 6*d.* per day. Plock† estimates that a four-kiln plant to produce 400 tons per day costs 21,000*l.*, and when using oil for fuel the briquettes cost 1.55 dols. per ton, made up thus:—

	Dols.
Labour	0.41
Fuel	0.60
Repairs	0.15
Interest, depreciation, and overhead charges ...	0.20
Power	0.09
Royalty	0.10
	1.55, or, say, 6*s.* 6*d.* per ton.

Dr. K. F. Stahl‡ states that the cost is 2 dols., or 8*s.* 4*d.* per ton, while in 1910 we were informed that at a plant in England the cost when working on pyrites was 2*s.* 11*d.* per ton, exclusive of interest and depreciation.

The American Gröndal Company state that with coal at 12*s.* per ton and common labour at 1*s.* per hour, and working 12-hour shifts, in America the cost is as follows:—

	s.	*d.*
Total labour, including superintendence and producing	1	5½
Repair and maintenance, labour and material	0	11
Power	0	2
Fuel	1	0½
Miscellaneous and general	0	5
	4	0

When treating pyrites residues the action of the hot acid gases on the cars and the walls of the kiln appears to have been very serious in some cases, and recently an improvement in the design of the kiln has been made at the Helsingborg Copper Works by Mr. Arthur Ramén, which is said to have very much improved matters in this respect and thereby reduced the cost of the briquettes. These improvements consist mainly of the provision of water-cooled walls through the combustion chamber, special provision for protecting the cars from any flame action, great control of the flame in the kiln, and the utilisation of the hot waste gases in the producers instead of live steam, and by these means the fuel consumption has been reduced from 10 per cent. to 7 or 8 per cent. A number of these Ramén kilns have been built in Germany, having a width of 2½ m. and giving an output of 100 tons per day when working on pyrite residues, and a plant capable of making 50,000 tons per annum was estimated to cost 10,000*l.* before the war. The cost per ton of briquettes before the war at a plant making 55,000 tons of briquettes per annum from magnetite concentrates is stated to be as follows:—

	Shillings per Ton. Labour.	Material.
Presses	0.280	...
Handling furnace-charging gear	0.066	...
Discharging and shunting cars	0.066	...
Producers	0.066	...
Coal, 8 per cent. at 15*s.* per ton	...	1.20
Repairs:		
Producer 0.03		
Kilns 0.06		
Cars 0.05		
Presses 0.17		
Car-handling gear 0.03		
		0.34
Sundries		0.10
Lubrication	0.030	0.04
Power	0.145	...
Foreman	0.090	...
	0.743	1.68

Total per ton of briquettes, 2.42 shillings = 2*s.* 5*d.*

These costs cover the process from the time the ore is placed in the press hopper up to the discharge of the briquettes from the kilns. The costs of unloading the ore, loading the briquettes, depreciation, and interest must be added, and will, of course, depend on the situation and on the arrangements adopted.

We are indebted to Mr. A. Douglas Tisdall of the Gröndal Kjellin Company for the foregoing particulars regarding this type of plant. The Gröndal plant has been very generally adopted for magnetite concentrates and other fine ores. By this method magnetic ores are converted to hematite, and, in fact, if the process is properly conducted, whatever its original form, the iron in the burnt briquettes will be found to be almost completely in the form of iron peroxide, Fe_2O_3—a very decided benefit—moreover, the sulphur content is very much reduced.

Among the processes of the third class probably the best known and most used is that proposed by Schumacher for the utilisation of flue-dust, which consists of mixing the fresh flue-dust with about 10 per cent. of water and a solution of magnesium chloride in sufficient quantity to give about ½ per cent. of $MgCl_2$ in the finished briquette. The magnesium chloride acts merely as a catalytic agent. The mixture is usually subjected to a pressure of about 3 tons per square inch, and the resulting bricks are air-hardened for from 18 to 48 hours, depending on the material used.

The flue-dust, or at least about half of it, should be quite fresh and still warm, the remainder can be old dust, of which many plants have large accumulations. When there is a large proportion of lime present it has been found necessary to slake this by introducing steam into the mixer, in order to prevent it being slaked by the moisture in the briquettes themselves, which it would then break up by its expansion. The cementing action is apparently due to the conversion of the oxide of iron to $Fe_2(OH)_6$. In addition to magnesium chloride, $CaCl_2$, $FeSO_4$, and pickling liquor from galvanising works have been used in this process with success.‖

All pieces of coke over, say, half an inch should be screened out of the dust, as they interfere with the production of sound briquettes by introducing large surfaces where no cementing action occurs. It is claimed for this process that it renders all the coke-dust contained in the raw material available as fuel in the furnace, but it seems more probable that a large proportion of the carbon contained in these small particles of coke is dissolved by the CO_2 of the furnace gases and never becomes available as fuel, and our experience certainly indicated no noticeable saving in fuel when using about 15 per cent. of briquettes. As long as the briquettes are well made this process affords a cheap method of using up flue-dust, but we found that if we used briquettes of which the resistance to a crushing load was below 10 cwt. per square inch on a briquette measuring 9½ inches by 4½ inches by 3 inches, the output from the dust-catcher increased, the furnace became stiff, and it was cheaper simply to break them up and mix the pieces with new flue-dust and start again.

It is said that in Austria, Germany and Belgium the total cost is from 1*s.* 3*d.* to 2*s.* per ton, and over many months at Lackawanna with very inefficient handling and elevating arrangements a cost of 2*s.* 6*d.* per ton was maintained,† a figure which is confirmed by our own experience. The cost of the magnesium chloride worked out at about 2½*d.* per ton of briquettes, in 1914, when using 50 per cent. magnesium chloride in the form of crystals.

The magnesium chloride process for briquetting flue-dust is, or was, in operation at Dortmund, Seraing, and other places on the Continent before the war, and appears to have found some favour in America. Simple as it appears, the process requires careful watching when the ores used are variable, but it can and does produce useful briquettes cheaply. Undoubtedly the proportion of fine coke contained in the flue-dust has a very important effect on the result, and we found that when the proportion exceeded about 30 per cent. it became difficult to produce good briquettes at all. It should be said in this connection that our conditions were undoubtedly difficult, owing to the constant and considerable variations in the coke, ores and limestones used.

Another process proposed by Schumacher is intended for the briquetting of magnetic concentrates. The concentrates are mixed with 8 per cent. of finely ground raw spathic ore, and 4 per cent. of finely ground hydrated lime. The mixture is pressed and steamed in an autoclave for about six or eight hours at a pressure of 150 lb. per square inch. The magnetites in this case are left unaltered, and the sulphur content in the raw materials is not reduced. Briquettes made in this way from magnetites have been used in Siemens furnaces, but not, as far as we are aware, in blast-furnaces.

While we have seen briquettes made by both these processes, and have succeeded in making them ourselves experimentally, we were not very successful when we attempted to do so on a commercial scale. We had incessant press breakdowns, but there is reason to believe that the materials treated, which, as it has been pointed out, were variable, required panning as well as mixing before pressing, and the necessary plant for doing this was being installed when the experiments were stopped by a series of strikes in the works, and the outbreak of war has prevented them from being renewed.

The Scoria process, which has been very fully described by Stütz,‡ consists of adding 5 per cent. to 10 per cent. of granulated slag and 4 per cent. of lime to the ore or flue-dust to be treated. In order to make the binder hydraulic the mixture is then subjected to a moderate steam pressure in a rotary drum. This also effects the complete and intimate mixing of its contents, which are afterwards pressed into briquettes and steamed in an autoclave for about 10 hours under a pressure of about 10 atmospheres. The cost, according to Stütz, is about 1*s.* 4*d.* per ton, and the resulting bricks are said to give excellent results in the furnace.

In the Weiss process‖ limestone is added to the ore or flue-dust, together with about 5 per cent. of powdered hydrated lime. The mixture is pressed into briquettes under a pressure of about 2 tons per square inch, and the briquettes, suitably stacked on special bogies, are then run into the hardening chambers, where they are first subjected to the action of cold CO_2 at a pressure of 300 lb. per square inch, and afterwards for about four

* *Cassier's Magazine*, July, 1905.

† H. Louis, Journal of the Iron and Steel Institute, 1904, No. I, page 40.

* *Stahl und Eisen*, 1913, vol. xxxiii, page 276.

† *Iron Trade Review*, vol. xcii, page 1017.

‡ Transactions of the Engineers' Society of Western Pennsylvania, vol. xxix, page 641.

* Transactions of the American Institute of Mining Engineers, vol. xlvii, page 338.

† *Iron Age*, 1913, vol. xci, page 70.

‡ Transactions of the American Institute of Mining Engineers, 1913, vol. xlvii, page 324.

‖ *Stahl und Eisen*, 1911, vol. xxxi, page 1539.

hours to the action of CO_2 mixed with the waste gases from the retort furnace in which the CO_2 is produced by heating limestone. The briquettes are said to be hard and porous, and to cost about 2*s.* per ton, but the process is not suitable for clayey ores.

The Trainer, Pioneer and the Pollacsek processes use as a binder sulphite liquor or sulphite pitch (also known as cell pitch), which are produced by evaporating the waste liquors resulting from the preparation of pulp for paper-making by the sulphite process. Sulphite pitch is soluble in water, and briquettes depending on this alone as a binder do not stand the weather. In the Pioneer process the ore, with about 4 per cent. to 8 per cent. of sulphite pitch, is pressed and burnt in kilns. In the Pollacsek process the ore, mixed with sulphite liquor as a binder, is heated and partly dried in a rotary drum and then pressed, the briquettes being then allowed to stand to harden. The control of the temperature during heating and drying is most important, and sound bricks depend entirely on maintaining the correct temperature. It has been stated that the cost of briquettes made by these processes is about 2*s.* 3*d.* per ton, but we have no confirmation of this claim.

There have been many other binders proposed, such as peat, clay, salt, molasses and filter-dust, but we have not been able to ascertain that any of these have found wide application.

In general, so far as we are aware, excepting in the case of the Schumacher flue-dust process, true briquetting processes are not cheap to work, and good evidence in support of this view may be found in the undoubted popularity of the other methods of ore preparation, for which such low costs are not generally claimed.

Our experience of other briquetting processes includes manufacture in a standard wire-cut plastic brick machine, followed by stove drying and burning in ordinary chamber kilns. The ore was Menera screened ore, a difficult material to treat, and the result was not by any means bad, and indicates that with cheap labour an expensive press may be quite unnecessary when the briquetting is carried out at the blast-furnace plant. In this connection it appears that now, when machinery is difficult to get and good lumpy ores scarce, the possibilities of briquetting the fines, particularly from calcined and possibly some other ores, by comparatively crude methods akin to shop moulding merit consideration. Any suitable building with a heated cast-iron plate floor and the simplest type of brick kiln might suffice in many cases to convert ores, which in their natural state are too fine for easy smelting, into vastly superior briquettes at a not unreasonable price as things go to-day.

It will perhaps be of interest at this point to note the leading characteristics of a few of the most successful briquetting machines. In connection with the Schumacher process a very good press, indicated diagrammatically in Fig. 1, was developed, in which the fulcrum of the lever applying the pressure to the mould is carried on the end of a ram sustained in position by oil under a pressure of about 100 atmospheres.

The oil cylinder is connected to a cylinder of nitrogen, which provides a simple means of maintaining the required pressure. With this arrangement the total pressure exerted by the ram on each briquette is easily recorded on a continuous recorder, and alarm bells are rung when the pressure becomes insufficient or excessive. This device has been adopted in presses recently made by the General Briquetting Company, of New York. Such a press exerts a pressure up to about 6,000 lb. per square inch on the briquette, requires about 35 h.p. to drive it, and has an output of 7 tons of ore briquettes per hour.

A very simple and cheap machine has been developed by Messrs. T. C. Fawcett, Limited, in which a cylinder fitted with four moulds arranged symmetrically about its circumference is rotated by suitable pawl gear to bring each mould successively into the required position for filling, pressing and extraction of the briquette. The essential features of this machine are indicated in Fig. 2. When the ram, A, is in its backward position in the bottom of the feed-hopper B, the ore falls in front of it, and as the ram travels forward on its next stroke the required amount of ore is pushed into the mould and pressed into a briquette. At the same moment the ejecting lever C has descended and pushed the plunger plate in the top mould, and with it the plunger plate in the bottom mould — these being connected — to the bottom of their stroke, thereby preparing the top mould to receive its charge of ore and at the same time ejecting the briquette from the bottom mould on to a suitable belt conveyor. The connecting-rod has embodied in it an hydraulic device, D, which, while acting as a safety appliance, provides means for easily indicating and adjusting the pressure actually exerted by the ram.

Fig. 1.

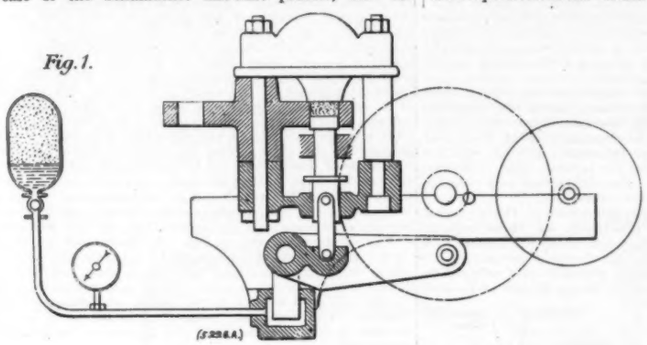


Fig. 2.

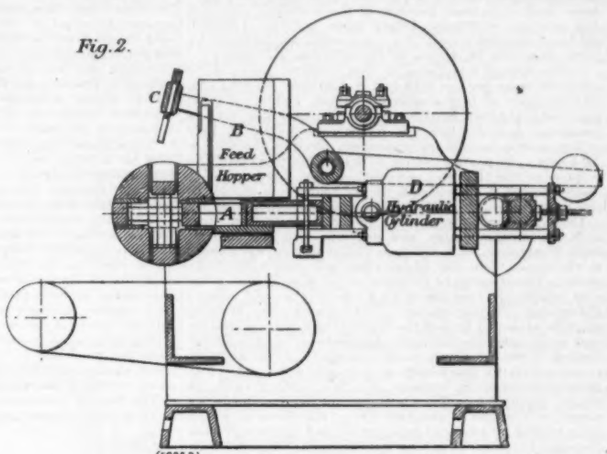
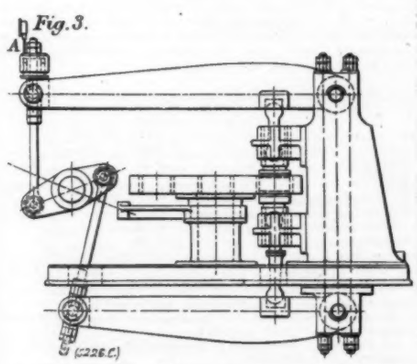


Fig. 3.



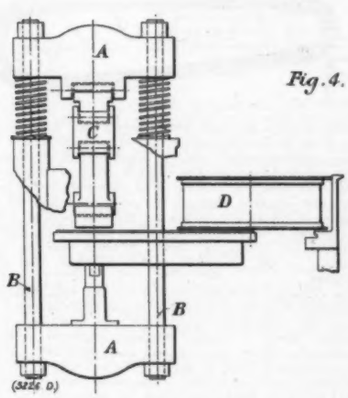
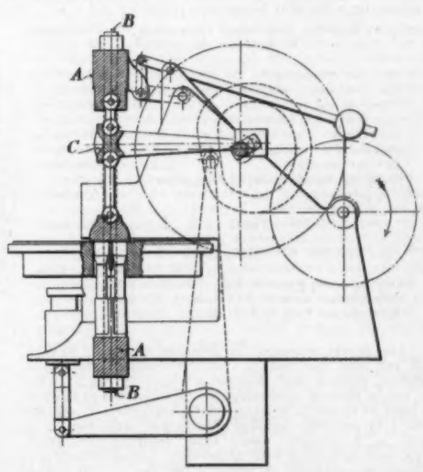


Fig. 4.



This machine has a capacity of about 50 tons per ten-hour day, and would cost before the war something approaching 400*l.*

We are informed by Messrs. Fawcett that the machinery for a complete plant, with elevators, conveyers, and a machine of this type, cost about 1,250*l.* in 1913.

In the Bradley and Craven press, which is of the horizontal table type, the briquette is pressed from both sides simultaneously. The means by which this is effected is shown diagrammatically in Fig. 3, copied from a sketch supplied by the makers, which is self-explanatory. The advantage of this arrangement is obvious, for it halves the thickness of ore through which the pressure has to be transmitted, and thereby much reduces the holding-up effect of the friction between the ore under pressure and the sides of the moulds, which, in the case of a thick briquette pressed on one side only, may materially reduce the actual pressure to which the ore is subjected on the side remote from the pressing ram.

It will be noted that on the tension-rod operating the top lever an annular hydraulic cylinder and plunger are inserted between the nuts and the lever for recording the pressure exerted by the ram. The arrangement is a very convenient one, because the failure of an hydraulic leather, if it occurs, results in a stoppage of only a few minutes, as the whole appliance can be removed and replaced by another by removing the two nuts on the tension-rod.

In this machine the use of springs under heavy loads has also been avoided, and a very simple and effective design of connecting-rod end provides the necessary safeguard against damage by excessive pressure. A machine of this type having an output of about 50 tons per ten-hour day when working on flue-dust, and up to about 70 tons on denser material, cost about 900*l.* in 1914.

The "Emperor" machine, made by Messrs. Sutcliffe, Speakman and Co., Limited, is designed to press the briquette from both sides, and at the same time entirely to relieve the frame from the greater stresses due to the operation. The pressure is applied through the toggle levers C, which work within a self-contained frame made up of the top and bottom beams A and the heavy steel connecting bolts B, as indicated in Fig. 4, which is taken from drawings supplied by the makers. As soon as the downward movement of the upper pressing ram is resisted by the ore, the action of the toggle causes the frame to rise, and the lower ram, which is carried on the lower beam, comes into operation. The pressure to which the briquette is subjected is entirely controlled by adjusting the quantity of material fed into the mould from the feed-hopper D. This can be varied while the machine is running, and the machines are arranged to give pressures up to 10 tons per square inch.

Of the processes coming within the fourth class probably the most widely used is that of nodulising in rotary kilns, on the general lines of those used in cement manufacture. In recent plants the kilns run to about 125 ft. in length and 10 ft. in diameter. The thickness of the firebrick lining is usually about 9 in. to 12 in. in the hottest part of the kiln, and it is reduced according to the circumstances towards the cooler zones. Chrome bricks are said to have been used with good results in some cases, but the life of an ordinary firebrick lining is about four to six months. The kiln is set at an inclination of about ¼ in. per foot and fired at the lower end, generally with pulverised coal, though oil, producer gas and blast-furnace gas are all used.

The kiln is rotated at a speed depending on the material treated, and the ore, which is fed to the kiln by means of a rotating table or other suitable device, in its passage through the kiln is first dried, then it is desulphurised, and finally, owing to the rolling motion imparted to it by the turning kiln, it agglomerates into nodules varying in size from a pin-head to about 1½ in. diameter when the plant is working properly. The nodules are discharged

at the lower end of the kiln at a bright red heat to a cooler, and after cooling are ready for immediate use.

The product of this process is generally magnetic, and the surface is glazed. This reduces its porosity and retards its reduction in the blast-furnace, but notwithstanding this, if the kiln is carefully worked, it can produce quite a good smelting material that can be used without any special difficulty up to 50 per cent. of the burden in furnaces making low silicon pig-iron, and is used up to 100 per cent. in certain cases,* and so far as our experience goes it is far preferable to a soft and friable and consequently inferior briquette in a fast-driving furnace. The process is very effective for the reduction of sulphur in the ore, and it has been stated that nodules suitable for the blast furnace can be produced with raw material containing up to 7 per cent. of sulphur.

In some cases the operations have been divided by desulphurising in one kiln and nodulising in another, but this system has not been generally adopted. In the case of certain ores, as the Mayari ore of Cuba, binders have been used to increase the size of the nodules. Through the courtesy of Messrs. Edgar Allen and Co., Limited, we have received a copy of a communication received by them from Mr. W. Meade of Philadelphia, as follows :—

"The cost of nodulising in this country amounts to about 60 cents per ton with fuel at 2.50 dols. per long ton. The amount of fuel required is about 250 lb. of good gas coal (13,000 British thermal units) per ton of nodules. A rotary kiln 8 ft. in diameter by 100 ft. long will give an output of approximately 150 tons of cinder in 24 hours. In pyrites cinder it is possible to reduce the sulphur to less than 0.1 per cent., and in many cases we have reduced it as low as 0.05 per cent." In regard to the preparation of pulverised coal, Mr. Meade says : "The coal should be dried so that it contains less than 0.5 per cent. moisture, and pulverised so fine that at least 95 per cent. of it will pass a sieve having 100 meshes to the linear inch, and 85 per cent. will pass a 200-mesh sieve. The steps to be followed in the preparation of the coal consist of (1) crushing to a size of 1 in. and under ; (2) drying ; (3) pulverising. The apparatus for burning must be arranged to feed the coal to the furnace regularly and in the quantity desired. Apparatus is obtainable for feeding to the furnace as small a quantity of coal as 25 lb. per hour up to practically any quantity desired. The apparatus generally consists of a bin holding 12 to 24 hours' supply of coal. The latter is fed from this by means of a properly designed worm, the speed of which is controlled by a special cone pulley, and which regulates the quantity of coal fed to the furnace. The coal falls from the worm into a mixer, where it is mixed with air supplied by a fan and blown into the kiln.

Cost of Plant for preparing Pulverised Coal (capacity, 80 tons per day).

	Dols.
One pot crusher set	750.00
One coal-dryer with stack erected	4000.00
Three elevators	1200.00
One mill with foundations ...	4000.00
One bin	300.00
Motors with wiring, &c.	2000.00
Labour erecting	1000.00
Building, incidentals, and engineering fee	7500.00
Total	20,750.00

Cost of preparing Pulverised Coal (in above plant).

	Dols.	Dols.
Drying coal, ¾ ton at 3.00 dols. ...	2.25	
Attendance, two at 1.75 dols. ...	3.50	
Attendance, two at 1.50 dols. ...	3.00	
		8.75

"The power required for grinding is about 90 h.p., and the cost per ton of coal, including attendance, supplies, repairs, and interest is about 40 cents. Coal for use in heating metallurgical furnaces should contain at least 35 per cent. volatile combustible matter, and not over 1.25 per cent. sulphur nor 12 per cent. ash. Gas slack is commonly used. Coal fulfilling the above requirements burned with 25 per cent. excess air will give a flame temperature of about 1,760 deg. C. If higher temperatures are desired the excess air may be reduced or the air preheated by hot-blast stoves. With the theoretical amount of air a temperature of 1,985 deg. C. may be obtained.

"In metallurgical furnaces the ash does not adversely affect the charge. Some collects on the bottom of the combustion chamber, some passes out of the stack, and some collects in the base of the latter. Where regenerative ovens are used these should be provided with straight baffle walls in place of checker-work, and provided with eye-holes through which the ashes can be scraped off the walls, and out by means of a hoe.

"Using coal containing not more than 1¼ per cent. of sulphur it is easily possible to keep the sulphur in the product at the same figure, which would be obtainable with the coal if fired on grates or in producers.

"Provided the air pressure used to carry the coal into the furnaces is kept low, no difficulty will be experienced with the furnace lining. If a high air pressure is employed, the effect is to destroy the furnace walls. Air from a fan at 6 or 8 ounces pressure is employed, but this is reduced in the mixer, so that it is at not more than ¼ to ½ ounce just before it leaves the pipe.

"With proper care in designing the coal-pulverising plant and storage bins, the danger of explosions and fires are overcome. If the coal is allowed to stand in the bins too long it may take fire. This need occasion no alarm, however, as the burning coal may be fed out of the bin into the furnace, and the bin so emptied."

* Transactions of the American Institute of Mining Engineers, 1913, page 2515.

The cost per ton of nodules seems to vary considerably according to circumstances. The estimated cost per ton in a plant designed in 1909 to make 1,000 tons per day was 3*s.* with coal at 12*s.* per ton, but according to several writers it is found in practice that the cost is generally from 4*s.* to 5*s.*, the labour being about 1*s.* 6*d.* per ton. The fuel consumption when using powdered coal is about 8 per cent. to 12 per cent. of the weight of the product, or say 1*s.* 6*d.* per ton with coal at 15*s.* The total cost of a two-kiln plant complete with the building and railroads was given a few years ago as, roughly, 30,000*l.*

The process requires very careful watching if it is to produce a reasonably constant product. It is liable to very serious interruptions, caused by the formation of the well-known rings of melted or clinkered ore in the hottest part of the kiln. Many proposals have been made for preventing these, and much may be done by careful control of the temperature and of the length of the flame, but so far as we are aware no absolute preventative has been discovered, unless it be the chain-scraper installed at the Illinois Steel Company's plant, and referred to by Mr. Brassert.* Otherwise the only satisfactory cure is to shut down and cut the obstruction out, and the loss of output and damage to the lining caused by this increase the cost of production to an extent which would certainly not be suspected by the uninitiated observer of this apparently simple and continuous process.

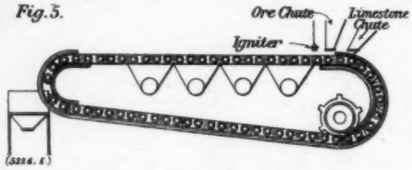
Notwithstanding this, there is fairly reliable evidence that at a plant where nodulising kilns and a Gröndal briquetting plant are working on the same ore side by side the nodules are now produced for about 1*s.* 6*d.* per ton less than the briquettes.

We have used both the briquettes and the nodules from this plant, and find the former rather too friable for fast driving, and the slipping that results from this causes an increase in the fuel consumption greater than that required to smelt the more refractory nodules, and for this reason we have preferred the latter. This, of course, only applies to these particular briquettes and nodules, but the point is not without interest.

We now come to the consideration of the so-called sintering processes. In practically all these cellular mass results, which if it has not been overheated is a most excellent raw material for the blast-furnace.

The first of these systems is probably that referred to in an English patent granted to Henry Aitken of Falkirk

Fig. 5.



in 1868 (Patent No. 352, 1868), which had for its object the coking or carbonising of iron ores, particularly those having carbonaceous matter combined with them, in such a way as to recover the volatile matters they contain. In this process calcination was effected by means of downward draught through a perforated hearth. The addition of water and steam during the process of burning, referred to in a recent American patent, was also fully described by Aitken in 1868. Several systems are in operation to-day, the best known of which will not be described.

The Dwight-Lloyd Process.—Very full descriptions of this process have been given by Gayley† and Klugh‡, from which the following particulars are extracted :—The machine, which is shown diagrammatically in Fig. 5, consists of a frame of structural steel supporting a sheet iron suction-box open at the top. Over this suction-box is pushed a train of conveyor elements called "pallets," each having a floor composed of herring-bone grates carried in the frame of the pallets, the bottom surfaces of which are planed, and thus make an air-tight joint with the horizontal top edges of the suction-box on which they slide. The ends of the pallets are also planed to make air-tight joints while the train of pallets is being pushed along. The movement of the pallets is accomplished by a pair of sprocket wheels, and each pallet is provided with four small rollers, which hang idle while the pallet is travelling over the suction-box, but serve to carry it on its return trip to the point of departure. When the pallets have passed over the suction-box, the rollers engaged in curved guides, which lead the pallets downwards and back under the suction-box. As they pass downwards after leaving the suction-box, each pallet breaks away from the train and drops on the upturned edge of the one just preceding. The shock serves to dislodge the sinter, which is automatically discharged by this means. There is thus a practically endless conveyer, any individual element of which can be removed for repairs and a new one substituted without stopping.

The ore is intimately and thoroughly mixed with the requisite amount of fuel and tempered with water, and the mixture is then fed automatically to the pallets in a thin layer from a simple funnel-shaped bottomless hopper and passes under an igniting device, for which purpose blast-furnace gas can be used, if available. The combustion thus started is carried downward by the air currents while the material is passing over the suction-box. The speed is adjusted to give sufficient time for the complete combustion of the fuel, and varies from about 10 in. to 36 in. per minute. The heat required to start the process is relatively small, and the cost of ignition correspondingly low. The amount of fuel is adjusted to provide just enough heat to cause the edges of the small pieces of ore in the charge to fuse together, and, as the fuel itself burns away, the product is a lumpy mass of material of very cellular structure. The sulphur is much reduced in the process, and workable sinter containing less than 0.10 per cent. of sulphur has been produced from pyrites residues containing 6.5 per cent. of sulphur.*

Although the resulting sinter is undoubtedly glazed to some extent, the product presents a large surface to the action of the furnace gases, and has been found to give excellent results in the blast-furnace. The process lends itself easily to the modifications required to treat different materials. It is stated that flue-dust, fine ore, and raw spathic ores have all been satisfactorily sintered either separately or mixed. When ores are treated alone, coke breeze or small coal is mixed with them to provide the necessary internal heat for sintering, but when flue-dust is used it generally contains an excess of fuel, which can be rendered useful by adding fine ore to the flue-dust until the carbon in the mixture is reduced to about 8 per cent. of the whole.

The Dwight and Lloyd system has recently been very widely adopted in the United States, and we understand with good results. Trouble was experienced in preventing the burning of the grate, as, even with most careful mixing, variations will occur at times, and the fire will then burn through the bed to the grate more rapidly at one place than at another. If steps are immediately taken to protect the grate there will be unburnt patches in the sinter. To avoid this trouble it is usual first to charge a layer of broken limestone on the hearth from a chute placed before the ore chute and arranged to spread the limestone evenly over the surface of the grate. This layer of limestone receives the layer of flue-dust or ore to be sintered and separates it from the bars, so that the fuel in the bed can be burnt right out, or so far as is found to be practicable. It also to some extent reduces the amount of ore which is unavoidably drawn into the suction-box by the draught.

The contents of the pallets are discharged on to a 1¼-in. grizzley screen, arranged to separate the lumpy sinter from the limestone and sinter dust, which are then screened again, all under ¾ of an inch being returned to the ore feed-hopper to be mixed up again and re-treated. The limestone, reduced in quantity by about 30 per cent., is returned to the limestone bunker and used again.

This method has been found quite satisfactory† and has reduced grate-bar losses to a very small item, and the admixture of a certain proportion of lime with the sinter is in no way objectionable. The cost of operation has frequently been given in various publications, from which the following are extracted :—

Cost of Producing Sinter by Dwight and Lloyd Process.

	(*a*) Dols.	(*b*) Dols.	(*c*) Dols.
Labour	0.17	0.18	0.24
Ignition	0.03	0.06	0.05
Power	0.12	0.16	0.09
Repairs and supplies	0.07	0.06	0.03
Interest, depreciation, and overhead charges	0.06	—	—
Royalty	0.20	—	—
	0.65	0.46	0.41

(*a*) Plock, *Iron Trade Review*, vol. xcii, page 1061.
(*b*) Klugh, Transactions of the Engineers' Society of Western Pennsylvania, vol. xxix, page 619.
(*c*) Maynard, Transactions of the American Institute of Mining Engineers, 1912, page 508.

On the plant referred to in column (*b*) the labour consists of one foreman, one machine operator on each turn, one oiler (day turn only), three labourers by day and two by night.

We understand that at an American ironworks where this system has been in operation for some time an excellent product is made at a cost of 57 cents to 60 cents per ton, including all that can be fairly charged against the process, and the whole plant required to give an output of 100 tons per day on flue-dust under actual works conditions is said to have cost about 4,200*l.* Plock‡ stated in 1913 that a plant having a capacity of 100 tons of sinter per day would cost 15,000 dols., or, say, 3,100*l.*

The system and machinery are simple and well adapted to the prompt correction of any irregularities, for the material is open to inspection the whole time, and the effect of any adjustment in the mixture, ignition, speed or suction can be observed almost immediately, and if necessary, in theory at least corrected before any large quantity of unsuitable product has been made.

Notwithstanding this great advantage, however, it appears that primarily everything depends on the thorough preliminary mixing of the raw materials to ensure regularity in the resulting sinter, and in the various descriptions of this process there are many indications that prevention is vastly superior to cure in this connection. The suction required is from 10 in. to 17 in. of water, and the volume of gases exhausted was stated to be about 52 cub. ft. per minute per square foot of grate area in plants described in 1915.

* Transactions of the American Iron and Steel Institute, 1915.
† *Iron Age*, vol. lxxxviii, page 422.
‡ Transactions of the American Institute of Mining Engineers, 1912, page 508.

* Transactions of the Engineers' Society of Western Pennsylvania, 1914, vol. xxix, page 619.
† Transactions of the Engineers' Society of Western Pennsylvania, 1914, vol. xxix, page 619.
‡ *Iron Trade Review*, vol. xcii, page 1061.

In a recent description* of a new and very complete plant installed at Mingo Junction, Ohio, it is stated that a machine having a grate area of about 93 sq. ft. produces 300 tons per day when working flue-dust. In this case a fan coupled to a 115-h.p. motor and capable of exhausting 25,000 cub. ft. of exhaust gases per minute is provided, which represents approximately 270 cub. ft. of gases per square foot of grate area per minute.

For the Huntington-Heberlein process the apparatus somewhat resembles a Bessemer converter in principle. A vessel about 9 ft. in diameter and 4½ ft. deep is fitted with a perforated grate placed about 15 in. above the bottom, and arrangements are provided for introducing air under a pressure of about 15 in. of water into the space below the grate. A fire is first built on the grate, and the ore to be treated and already mixed with some fine fuel is spread over it to the required depth. The blast is then turned on—setting up rapid combustion, which proceeds upwards through the charge. The heat developed causes the ore to agglomerate and form a cellular mass, which is removed, when burning is complete, by turning the converter over and letting the lump fall out on to screens. This breaks the mass into more or less serviceable sizes, and at the same time removes such fines as are formed, which can then be subsequently re-treated. The apparatus is simple, but care must be taken to prevent any channelling by the blast. The product is said to be fairly porous and to work well in the furnaces. It is claimed that sulphur, arsenic and zinc can all be driven off in the process. Klugh† states that the blast tends to lift the ore from the grate, and to keep it more or less in motion, and as a result the product is apt to be less sound than that made by the down-draught processes; though, on the other hand, Plock‡ says that very hard and dense sinter is made. Presumably in this, as in all other processes, much depends on the skill and judgment exercised by the operator.

The coal consumption when treating pyrites residues, for which this system has been found particularly suitable is about 12 per cent., and the working cost is approximately the same as other intermittent sintering processes. The plant is simple, and depreciation and general upkeep are said to be low.

It is of interest to note that in 1914 this process was in operation at the Gelsenkirchener Works at Gelsenkirchen, where it had superseded the Schumacher process for treating flue-dust, the plant for which was lying idle. Messrs. Huntington-Heberlein have very kindly furnished us with the following information relating to the cost of the plant and the product.

The capital expenditure involved naturally varies considerably with the local conditions, but, assuming that electric power is available, the approximate total pre-war cost per unit capable of producing 20 tons per 24 hours would be about 850*l.* for plants of not less than two such units and allowing about 30 per cent. of the total cost to cover foundations and buildings.

The power consumption is about 10 h.p. for 50 tons of daily capacity. The cost of labour in plants having a capacity of 100 tons per day is roughly a full average day's wage for every 10 tons of agglomerate produced, and with favourable labour conditions and cheap fuel the total pre-war working cost, including depreciation and royalty, was about 3*s.* 6*d.* per ton.

The Greenawalt process appears to have found considerable favour in the United States in recent years for the treatment of fine ores, concentrates, blast-furnace flue-dust, and similar materials. A general idea of the plant is shown on page 306; for the illustrations, as also for the description of the process which follows, we are indebted to Mr. F. B. Dutton, vice-president of the American Gröndal Company :—

"The mixture of fuel and ore, suitably moistened, is placed, by a mechanical charging car, in a layer of proper thickness, on a grate surface suitably protected by a porous medium such as crushed limestone or other inert substance, and then ignited while subjected to a down draught from a suction fan.

"The apparatus carrying the grate is known as the pan, and is so arranged that on the completion of the burning of the charge, which may take from half an hour to an hour, the pan can be tilted and emptied, and is then ready for another charge."

The plant, as shown in Figs. 6 and 7, page 306, having two pans 9 ft. 4 in. by 24 ft., has a capacity of 400 tons of sinter per day when using flue-dust containing not more than 11 per cent. of carbon, and the total cost of this particular plant when erected was estimated quite recently as 114,000 dols., or about twice the pre-war cost. Mr. Dutton estimates the cost of working, based on American conditions and first-class practice, as follows :—

	Dollars per Ton of Sinter.
Power at 1 cent per kilowatt hour	0.144
Labour of six men per 10-hour shift	0.087
Fuel for ignition	0.015
Material for repairs and maintenance	0.025
Tools, lubricants, and miscellaneous supplies...	0.007
Yard switching	0.027
Shop expenses	0.015
Overhead and general works expenses	0.020
Water	0.001
	0.341 per ton of sinter.

In this cost labour is taken at an average of about 12*s.* 6*d.* per day. The above does not include interest or royalty.

When referring to the Greenawalt process in 1913, A. F. Plock* stated that a plant consisting of one pan measuring 7 ft. by 12 ft., together with all necessary conveyors, appliances, and building, cost 10,000 dols., and produced up to 40 tons per day at a cost of 75 cents per ton, while Hansell† states that the cost of a Greenawalt plant is about one-third of the cost of a rotary kiln plant of equal capacity, and, further, that a five-pan plant with a total capacity of 500 tons per 24 hours needs five men to work it, and produces sinter at a cost which will not exceed 2*s.* 6*d.* per ton. The suction used in this process is about 20 in. of water. The time required for ignition of the surface of the chargers is about one minute, the ignition flame being extinguished as soon as the surface of the charge is a glowing red.

As in the Dwight and Lloyd process, careful mixing of the fuel and ore and adjustment of the moisture content of the charge are important. In regard to the latter Hansell† states that magnetic concentrates require about 7 per cent. to 8 per cent. and, while 10 per cent. is too much for this class of material, it has been found that pyrites residues need from 15 per cent. to 20 per cent., and Mayari ore as much as 30 per cent.

The fuel consumption varies considerably with the class of material treated, and Hansell states that it may be as low as 2 per cent. with magnetic concentrates, and 6 per cent. to 8 per cent. with pyrites residues. Paraffin, crude oil, natural gas, and blast-furnace gas have all been used for igniting the charge, the amounts required per ton of sinter being apparently 1.5 gallon of paraffin, from one-third to one gallon of fuel oil, 90 cub. ft. of natural gas or its thermal equivalent in such other gas as may be used.

The Greenawalt process is efficient in respect to the reduction of sulphur in the charge, but it is said to be necessary to use fuel low in sulphur for this purpose, but this would presumably apply equally to other sintering processes also. The plant is simple in operation, and the cost of upkeep is low. The product is good, and with care can be made to stand shipment without an excess of fines resulting.

In order to overcome the trouble experienced through damage to the grates in down-draught processes and at the same time automatically return all fines to the burning zone, Harding‡ has proposed a machine in which the sintering is carried out in a vertical shaft, the necessary air for combustion being drawn upwards by means of an exhaust fan connected to the closed top of the furnace. The sintered matter is discharged at the bottom by means of a rotating cone, which assists in keeping the column of material free and open.

The movement in opposite directions of the air for combustion, and the ore charge itself, should result in the best use being made of the heat of the product of combustion for preheating the charge, while the incoming air should cool the outgoing sinter, so that no mechanical parts are subjected to excessive heat. After the preliminary ignition no further ignition fuel would be needed as the process would be continuous.

The West process of sintering is carried out by means of heat derived from an external source. The material to be treated is dropped into a highly-heated chamber, which is so designed that while falling from the ceiling to the floor the charge will be sufficiently heated to cause the particles to adhere to one another as the pile increases.

Fig. 8.

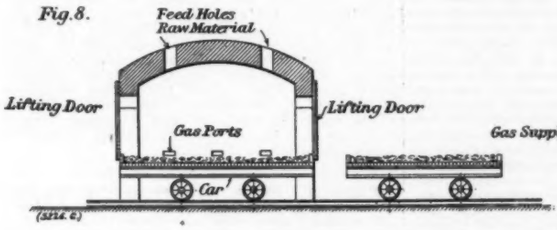
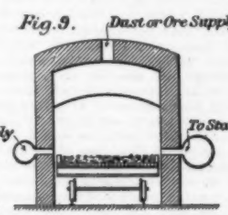


Fig. 9.



The apparatus for doing this, shown diagrammatically in Figs. 8 and 9, takes the form of a short tunnel furnace, the firebrick hearth of which is carried on cars, which are passed in empty at one end of the furnace and withdrawn at the other end when the required amount of sintered material has collected on the hearth. Suitable gas-burners are arranged along one side of the furnace, and the outlets to the stack are situated along the opposite wall.

The method of operation is as follows :—A layer of fine ore, flue-dust, or other material, thick enough to prevent the charge sticking to the bricks, is placed on the hearth of a car, which is then pushed into the furnace. The doors covering the inlet and outlet openings for the cars are closed and gas is put on, and the chamber heated up to the required temperature. The material to be treated is then fed in slowly from the top and scattered by a mechanical contrivance, so as to fall evenly over the area of the hearth. During their descent the particles are heated up so that the surfaces become soft, and on coming to rest at the bottom they adhere one to another and build up a pile of sintered material on the hearth.

When sufficient has accumulated, and this depends on the capacity of the furnace, the operation is stopped, the doors are opened and the loaded car is pushed out and replaced by another, which has been prepared in readiness. The doors are then closed and operations recommenced. The lump of sinter is quickly discharged and broken up, the fines being screened out and returned to be re-treated. The sinter produced in this way is of good quality, and has been used with satisfactory results in the blast-furnace in varying proportions up to 30 per cent. of the burden.

It is stated that this process gives a very regular product, as each portion of the charge is submitted to the full effect of the heated furnace. No special treatment or careful mixing of the raw materials is needed, and the possible variations in raw materials such as flue-dust do not affect the result.

In his description of the process West* states that the cost of fuel is 1*s.* per ton, and of labour and repairs also 1*s.*, making 2*s.*; and Plock† gives the total cost, including royalty, as 3*s.* He also states that the cost of a furnace with a capacity of 40 tons per day is about 500*l.*

Having now described the principal processes in operation to-day for briquetting or agglomerating iron ores, we venture to make the following general observations.

It is in our opinion very necessary to fit to briquetting presses an indicating and recording device showing the actual pressure to which every briquette is subjected on the side remote from the ram. The briquette moulds should be tapered, the larger end being that through which the briquette is removed. The reason for this is that the greatest wear on the moulds takes place just where the ore closes up on itself as the pressure is applied, with the result that the mould, if originally parallel, becomes barrel-shaped and the briquette has to be withdrawn through a section smaller than that in which it was pressed, and cracks are likely to be set up which may have serious results when the briquettes are stacked for burning.

Processes depending on pressure alone are not, in our opinion, likely to produce very satisfactory briquettes for use in the blast-furnace. The briquettes are very dense, but they do not stand weathering, and for the reasons already given they are not suited to ores showing any great loss on calcination. In general, these processes are said to be expensive to work when everything is taken into account. The Ronay process, which has perhaps had the greatest success of any of this type, appears, in spite of all estimates, better suited for treating such materials as metal borings, for which it has been extensively adopted.

Briquetting processes of the second class can in general be made to give a satisfactory product without an undue proportion of fines, and for these we believe that the English makers of briquetting machinery produce plant which gives excellent results. As regards kilns or furnaces the Gröndal type, which has been well tried under very varied conditions, has probably proved to be the most elastic. It can be relied on to give reasonably good, and in many cases most excellent, briquettes, particularly for use in the open-hearth steel furnace. Briquettes made by this process from many works situated in widely distant countries have come under our notice, and even after shipment the quality may usually be described as good, but certainly in one case within our knowledge they do not always stand shipment and handling too well, and it must be admitted that cargoes received from more than one source have contained from 5 per cent. to 30 per cent. of fines on arrival at the works, which, although it points to varying conditions of briquetting, is also a strong argument in favour of briquetting ores at the blast-furnace plant.

The Schumacher flue-dust process is probably the cheapest of all true briquette processes, and seems to have been successful in many widely separated works; but the benefits claimed for it on account of the reputed recovery as useful fuel of all the small coke contained in the flue-dust are, in our opinion, open to question. As we have said, our experience has been that when working in our furnace burden, 15 per cent. of apparently sound flue-dust briquettes, there was certainly no corresponding reduction in the fuel consumption, and we formed the opinion that the briquettes crumbled up comparatively high up in the furnace and that a very large proportion was blown out again as dust. In any case it appears to us that if the flue-dust briquette is porous, the small coke it contains will be in excellent

* *Iron Age*, 1917, vol. xcix, page 1299.
† Bulletin of the American Institute of Mining Engineers, 1912, page 539.
‡ *Iron Trade Review*, 1913, vol. lii., page 1061.

* *Iron Trade Review*, 1913, vol. lii, page 1061.
† Transactions of the Canadian Mining Institute, 1913, page 295.
‡ *Iron Age*, 1916, vol. xcviii, page 138.

* *Iron Age*, vol. xv, page 955.
† *Iron Trade Review*, 1913, vol. lii, page 1061.

condition to facilitate the solution of its carbon by the carbon dioxide of the furnace gas, and, on the other hand, if it is not porous, it does not fulfil one of the most important requirements of a good briquette, and in either case the fuel is not used to the best advantage.

It is not without interest to note that, in spite of the very low cost of production for various briquetting processes, such as the Scoria and Weiss methods, they do not appear to have secured any such wide application as would be anticipated if all the advantages claimed had actually been realised in practice.

The outstanding disadvantage of all *briquetting* processes with which we are acquainted lies in the fact that in at least one stage, and usually more than one, every single briquette must be moved by hand, and this entails a heavy labour charge and risk of breakage, with resultant increase in the cost and in the fines in the product.

The rotary kiln handles relatively large quantities of material, and has been widely adopted in the United States. It is not subject to any charge as royalty and needs little labour, but the coal-grinding plant is expensive to run. This objection of course disappears if coke-oven or blast-furnace gas from furnaces using coal can be used for the particular ore treated. It has been pointed out that the process is liable to considerable delay from "ringing" in the kiln and also to variations in the product which, though generally fairly satisfactory, is dense and somewhat refractory, and for this reason the sintering processes appear to offer material advantages.

An interesting statement in this connection is made by R. B. Gerhardt,* who says that when nodules, which had formed three-eighths of the burden of a certain furnace, were replaced by the same proportion of sinter made from the same ore the furnace output increased by 5 per cent. while the fuel consumption was reduced by 5 to 8 per cent.

Sintering has made great advances in the last few years in America, and appears to warrant the very fullest investigations on account of the reputed low cost of operation, simplicity, and elasticity as regards the material treated. In this connection it may not be out of place to recall that when coke was costing 15*s.* per ton and Spanish iron ore could be delivered at our furnaces at a price equal to 4*d.* per unit of iron, the furnace flue-dust produced, if it contained 30 per cent. of iron and 30 per cent. of coke-dust—by no means uncommon proportions—contained iron to the value of 10*s.* and coke which had cost 4*s.* 6*d.*, representing a loss of 14*s.* 6*d.* per ton of flue-dust and, if only 20 tons per day is made, material to the value of about 5,300*l.* per annum is being thrown out of the furnace.

By sintering it appears all the iron would be recovered in a form suitable for use in the furnace, and, further, the excess of coke over and above that required to sinter the flue-dust itself would acquire its full value as fuel for sintering an additional quantity of fine ore.

We have no first hand knowledge of any of these processes, but reports received from those who have point to their product as most nearly fulfilling the requirements indicated at the beginning of these notes. The sintered material is not truly porous, but its structure is cellular and presents a proportionately large area to the action of the furnace gases. It is strong and stands weathering and stocking satisfactorily. It works well in the blast-furnace, and the cost of production under works conditions appears to compare favourably with that of all other processes.

There is no doubt that, suitably treated, many otherwise practically worthless ores can be made into most valuable material, and it is equally certain that it pays the ironmaster to do this himself. The analysis of the product will of course depend almost entirely on that of the raw material, and the cost of production with every process will depend very greatly on the particular conditions peculiar to the locality in which the plant is placed, a matter which may be materially effected by the difference in freight on the raw material and on the smaller quantity of the treated product. It must, however, not be overlooked that each time the product is handled a certain proportion is reconverted into dust, and for this reason a more perfect product, as it leaves the machine, is essential when the plant is distant from the blast-furnaces.

In conclusion, ore briquetting or sintering is not the simple operation it appears at first sight, and we think it cannot be too strongly emphasised that however successful a process may be when working any particular ore, it is not safe to assume that it will work equally well without modification on any other, and therefore every new material should be the subject of careful experiments before expensive plant is installed to treat it. Further, all estimates of costs submitted by those offering briquetting installations should be submitted to the most careful criticism, as the experience gained in our own operations and from our knowledge of various installations points to the necessity for making a very libreal allowance for the optimism of the inventor.

It is not pretended that these notes cover the whole ground, but it is hoped that they will prove of interest and serve as a basis for discussion on this important subject.

We have to thank the Ebbw Vale Steel, Iron and Coal Company for permission to use information extracted from their records, and Mr. Frederick Mills for his very helpful criticism of the draft of this report. Further, we wish to acknowledge our indebtedness for much contained in these notes to the many able writers whose works have been drawn on for information, and in addition to the names already mentioned we wish to express our thanks to Mr. J. E. Greenawalt and Mr. F. B. Dutton for the very complete information and drawings which they were good enough to send us, to Mr. R. B. Harrison for much useful information, and in particular to Mr. F. W. Daw, of Ebbw Vale, for many valuable suggestions.

* *Iron Trade Review*, 1913, vol. lii, page 364.

FUEL ALCOHOL.—The Advisory Council of Science and Industry of the Commonwealth of Australia, with whom the Alcohol Motor Fuel Committee is co-operating, is desirous of obtaining an efficient alcohol engine to exhibit at work at agricultural shows and other exhibitions in Australia, with the object of exciting public interest in the use of alcohol as a fuel. It is recognised that such engines may not be readily obtainable at the present time, but the committee would be glad to receive, for transmission to Australia, any available information as regards the cost of efficient alcohol engines and the probable date of delivery. For purposes of demonstration a small stationary engine of 5 h.p. to 10 h.p. would be preferred. It is suggested as an alternative that if it is impossible to obtain delivery of a suitable engine at a comparatively early date, a complete set of plans might be purchased, with a view to the engine being constructed in Australia. In either case it is desirable that any information sent to the committee should include particulars as regards patents by which the engines advocated are protected, and the arrangements which would have to be made in respect of royalty, &c., if it were decided to build now or subsequently in Australia. It is probable that the Advisory Council of Science and Industry of Australia will, on receipt of the required information and recommendations, order an engine (or plans if no engine be available) by cablegram. The secretary of the Alcohol Motor Fuel Committee, the Imperial Motor Transport Council, 39, St. James's-street, London, S.W.1., would like to hear promptly from any of our readers who may be interested in these proposals.

THE USE OF TAR OIL AS FUEL FOR DIESEL ENGINES.—In view of the recent Orders made by the Ministry of Munitions regulating the use of creosote and other oils produced from the distillation of coal, the Diesel Engine Users' Association have taken action to assist, as far as possible, in making arrangements for the necessary supplies of tar oils for their members. The present difficulty of obtaining a sufficient supply of petroleum residual oil as fuel for Diesel engines has led a large number of users to adopt tar oil. Difficulties have had to be contended with, as would naturally be expected, since the use of this class of fuel for Diesel engine work was extremely limited before the circumstances brought about by the war created a demand for a suitable home product as fuel in place of the imported residual petroleum oil which had generally been used. With the more extended experience now being gained in several quarters these difficulties are, however, gradually being overcome, and the discussion of the subject at a recent meeting of the association was evidence of the wide interest which is being taken in this development of Diesel engine practice. At the present time "Creosote Licences" are only being granted for a period of two months, but the association is hopeful that their members may shortly be able to obtain licences for the use of tar oil for longer periods, so as to facilitate arrangements in making contracts for regular supplies. The honorary secretary of the association has collected particulars of the requirements of the various members who use or who contemplate using tar oil, and these, together with other information, have been submitted to the Director of Munitions Petroleum Supplies.

THE LATE MR. EUSEBIUS VOGT.—Mr. Eusebius Vogt, chief engineer to the General Administration of the Swiss Federal Railways since 1901, died on the last day of August, we regret to learn from the *Schweizerische Bauzeitung*. Vogt was born in 1849, and was educated at Solothurn and in the Federal Technical High School, which he left in 1871 with the engineer's diploma. His first practical work was on light railways, under Herzog, at Freiburg. He soon joined the staff of the Jura Railway, and in 1875 became engineer to the municipality of Solothurn; as such he gave the town a new water supply and converted in this connection two wooden bridges over the Aar into iron bridges. After holding various appointments in the Canton, he became in 1897 chief engineer to the Swiss Central Railway, and accepted in 1901 the apointment which he occupied till his death. He had a chief part in the extension of the railway station at Olten junction, in the reconstruction of the stations and lines at Bern, Biel, Lausanne, Vallorbe, Oerlikon, St-Gallen and Enge-Zürich; and in the many alterations which the railway lines and stations at Basle have undergone in the last two decades. He built several new lines, and carried the Rickenbahn into the Linth and See districts. This latter scheme involved the construction of the Ricken tunnel, after the Gotthard and Simplon tunnels the longest tunnel of the Swiss railways; operations commenced in November, 1903, and the line was opened in October, 1910. Another important work was the diversion of the Sissach-Olten railway, 16 km. in length, which was lowered by 110 m. and the maximum gradient reduced from 28.26 to 10.5 per mille, with a saving in working expenses estimated at nearly a million francs; this work was commenced in 1912 and was finished last year. A very careful and conscientious engineer, Vogt also did much to improve the signal service and level crossings, and to facilitate traffic. Vogt had a severe illness in 1915, from which he recovered again. A man of strong character and a warm heart, he was greatly esteemed by his friends and colleagues.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—Government demands still continue to dominate the situation in the local steel trade, the entire output being practically devoted to purposes of war—munitions, shipbuilding and everything connected directly or indirectly with Army and Navy requirements. So urgent is this that a large percentage of the production actually goes hot from the rolling mills to the consumers' establishments, where it is speedily worked up as is most necessary. With all the existing feverish activity steel makers have the greatest difficulty in turning out material in sufficient quantity, and in most cases orders are booked many months ahead, so that there is little fear of any slacking-off this side of the New Year at any rate. More and more does the private trader find himself and his wants entirely crushed out by the pressure of work of the utmost national importance. As has been the case since quite the beginning of this year, the demands of the shipbuilding yards have been insatiable, every effort being made to speed up the construction of the shipping Controller's standard vessels. In every direction prices remain firm.

Malleable Iron Trade.—As in every other branch of industry, ceaseless activity continues to rule in the malleable iron trade, with every endeavour being made to bring the supply as nearly level with the demand as possible. In order to conserve a sufficient tonnage for naval and military work at home, Government restrictions regarding export are now being so strictly enforced that nothing is available for shipment abroad, this applying alike to iron and steel, both of which are in constant request. As evidence of what necessity can accomplish, shell discard steel has now reached a degree of importance which would not have been credited until quite recently, and bars rolled in this quality are as quickly disposed of as ever were those of the better grades.

Scotch Pig-Iron Trade.—The continued demand for pig-iron of all grades prevents any slacking-off in the busy conditions which prevail in every producing establishment, the sole anxiety being the unavoidable shortage of certain brands. Hematite is still very much in request, and in order to obviate the apparent scarcity every effort is being made to speed-up production, as the entire available output is rapidly absorbed in the local steel work. Under the existing circumstances of this heavy home demand, export is dwindling away to the vanishing point, the only shipments being some small lots urgently required by our Allies. Except where controlled, prices are all firm.

PERSONAL.—With a view to centralising their business in London the Stanton Ironworks Company, Limited, are removing their office on October 1, from 44, Coal Exchange, E.C. 3, to Maxwell House, Arundel-street, Strand, W.C. 2. Their new telegraphic address will be "Cobbles, Eastrand, London," and the telephone number "Central 6808." Mr. Arnold Longden, who has represented the company for some years on the London Coal Exchange, will continue to supervise the company's interests at Maxwell House.

HONOURS TO NAVAL ENGINEERS FOR MISCELLANEOUS SERVICES.—The King has been graciously pleased to give orders for the following appointments to the Distinguished Service Order:—To be Companions of the Distinguished Service Order: Engineer Lieutenant-Commander Frederick William Bromley, Engineer Lieutenant-Commander Maurice James Rogers Sharp, and Engineer Lieutenant-Commander Harold Hugh Huxham, for their services in vessels of the Harwich Force during the war. To receive the Distinguished Service Medal: Acting E.R.A., 4th Class, John Glyn Thomas, O.N. (Dev.).

THE SWEDISH STATE AND THE ELECTRIC POWER STATIONS.—The Swedish State has extended its regulating work to the supply of electric current and has made agreements with the Hemsjö and the Yngeredsfors Power Companies. The State's motives are to aid the interests of the general public and the National Household Commission by putting the supply of electric energy on ration in such parts of the country where such may be deemed expedient. It has, however, been considered to be to the interests of all concerned that the Hemsjö Power Company itself sees to the distribution of current under the new arrangement, subject to this being done under strict observance of the regulations laid down by the working committee of the Industrial Commission. The reduction in the supply will, in the first instance, apply to such large industrial concerns where shortage of raw materials or other conditions make a more pronounced limitation or reduction of working desirable from a national standpoint. The street lighting and the tramway traffic will be reduced, and all advertising illumination will be prohibited, as it has already been done long ago in other neutral countries. Further, such lines and transformer stations where the industries are not at work throughout the 24 hours are to be switched off at least six hours every night, as a rule from 10 p.m. to 4 a.m., which time is found most expedient out of regard to the farmers. All subscribers will be urged to exercise the greatest economy in the use of current, and the functionaries have to see to everything being carried out in the most rational manner, both at the power stations and at the subscribers' plants. The supply to private consumers and small concerns will, in the meantime, not be interfered with. The Hemsjö Power Company has been provident and lucky enough to secure fuel for its steam-driven power station for the whole of this and part of next year.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

South Yorkshire Coal Trade.—The manufacturing position has regained some of its more encouraging features, for there is not the same tension in the market as heretofore, and consumers are becoming reconciled by the assurances that, after all, the special provisions made for this area will work out well if only the collieries and agents are given time to adjust themselves to the new conditions. At the same time there is a heavy request for any surplus tonnage outside contract accounts, for all industrial users are building up winter stocks. Contract business, however, keeps pits fully occupied, and there is little passing for chance sales. Best steam hards are wanted in maximum tonnage for inland works and for Admiralty and Allied Powers' requirements, but the trade to neutrals is not large, though there is some prospect of Government arrangements increasing this. Outside any departure of this kind there is only small business passing. Small sorts come into the same category, whilst cokes and slacks enjoy their customary firm hard tone. The house coal position is now the most serious problem for the collieries and the dealers, the demand being far in excess of the volume of fuel available. Orders pour in, but railway difficulties alone prevent them being executed in the specified time. Quotations: Best branch handpicked, 20*s.* 6*d.* to 21*s.* 6*d.*; Barnsley best Silkstone, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire best brights, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire house coal, 17*s.* to 18*s.*; best large nuts, 16*s.* 6*d.* to 17*s.* 6*d.*; small nuts, 15*s.* 6*d.* to 16*s.* 6*d.*; Yorkshire hards, 16*s.* 6*d.* to 17*s.* 6*d.*; Derbyshire hards, 16*s.* to 17*s.*; best slacks, 12*s.* to 13*s.*; seconds, 10*s.* 6*d.* to 11*s.* 6*d.*; and smalls, 7*s.* 6*d.* to 8*s.* 6*d.* per ton at the pit.

Iron and Steel.—The maximum pressure is maintained in all branches of the steel and engineering trades, with little easing off in any direction, unless it is in work not directly concerned with the prosecution of the war. This category is not encouraged very much to-day, and the signs of any falling-off are rather welcomed than deplored, for firms are finding Government needs expand week by week, if not day by day. Marine specifications are gradually increasing, though it was believed in the middle of the summer that they had reached their zenith for this year. The output for the more famous shipbuilding centres, such as those on the Tyne, Clyde and at Belfast, is growing apace, and overtime is now being worked with consistent regularity. This remark applies with equal truth to all departments, including steel plate workers, castings and tool makers in particular. High-speed steel manufacturers find the further employment of the electric furnaces of great advantage, especially in the increased uniformity of output, the quality of the material, and the economy of working. The fact that electric furnaces cannot now be installed except with the licence of the Ministry of Munitions is attributed to a prospective shortage of electrodes, but in cases where the requirements for such furnaces are obvious and urgent, no difficulty has been found in securing the necessary permission. On the other hand this provision enables the authorities to regulate the erection of furnaces and secure for the national needs the maximum proportion of the resources available. These facts should be borne in mind by those who have been tempted to criticise the Ministry with undue severity. There is a curious position with regard to the tungsten supply. Supplies are undoubtedly coming to hand better than ever before since the outbreak of the war, but in some cases they are not being distributed with that evenness which seems desirable, for whereas in certain instances there is abundant tungsten for the work in hand, some firms have not enough to go on with. These latter firms seem to go on the lines of making high-speed steel whilst their tungsten supply holds out, and then proceeding on to carbon. Amongst the smaller and lighter lines the following are the busiest:—File makers, engineers' tool makers, saw makers, and firms with orders for spades, shovels, picks, hacksaws and drop-forged tools for service both here and with the Allied armies. The general overseas trade for all qualities of manufactured and semi-manufactured goods maintains a satisfactory level, but a drastic order of the Ministry of Munitions prevents the making of stainless cutlery on the ground of conserving the supplies of ferro-chrome for munitions purposes. This deals a severe blow at a prosperous trade, which was rapidly expanding overseas. The material market is unchanged.

Messrs. John Brown and Co., Limited.—The annual report of this company was issued this morning, and states that all departments have been busily engaged on work of the utmost national importance. Approximate figures only are given in the accounts, owing to the complexity of the questions which have to be dealt with by the firm in connection with the Ministry of Munitions and the Finance authorities. The net profit for the year is 494,029*l.*, which, with the balance brought forward, 147,797*l.*, totals 641,826*l.* After paying a dividend on the ordinary shares at the rate of 12½ per cent., less tax, the dividend on the preference shares, less tax, and transferring 150,000*l.* to the contingencies fund, there is left 176,451*l.* 10*s.* 7*d.* to be carried forward. The annual meeting will be held on the 27th inst., at Sheffield.

The Hardy Patent Pick Company.—This company declares to-day that a dividend of 8 per cent. will be paid on the ordinary shares, as against one of 5 per cent. last year.

ARMSTRONG COLLEGE.—The prospectus of day classes for the session 1917–18 of the Armstrong College has now been issued. The programme of studies is an extensive one, covering science, arts, letters and commerce.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—There is a steady firm feeling as regards Cleveland pig-iron, and prospects of early expansion of business are regarded as bright. Supply of all descriptions is plentiful. For the time being home transactions are few and small, consumers being very well placed, but renewal of activity should be experienced next week with the commencement of issue of October allocations, which promise to be on a very liberal scale. Some complaint is still made of delay in delivery, due to shortage of trucks, but, on the whole, deliveries to home buyers are going steadily forward. Exports to our Allies are now fairly heavy, though application for permits to ship to Italy are so large as to necessitate some curtailment. Business with France is still conducted through official channels. For home consumption No. 3 Cleveland pig-iron, No. 4 foundry and No. 4 forge are all quoted 92*s.* 6*d.*, and No. 1 is 96*s.* 6*d.*; and for shipment to our Allies No. 3 is 102*s.* 6*d.*, No. 4 foundry 101*s.* 6*d.*, No. 4 forge 100*s.* 6*d.*, and No. 1 107*s.* 6*d.*

Hematite Iron.—The recent blowing-in of an additional furnace on hematite iron should afford some little relief to a very stringent situation, but home consumers continue to take up such large quantities. In fulfilment of old contracts, however, rather better supplies have recently been going to our Allies. Negotiations are proceeding for fixing of further home business, but the situation as regards new foreign transactions is difficult and perplexing, as, in addition to other obstacles, export quotation is subject to extra charge in connection with the high neutral ore freights, and other expenses not easily explained and understood. Nos. 1, 2 and 3 stand at 122*s.* 6*d.* for home use, and are put at 141*s.* f.o.b. for export to the Allies.

Output of Pig-iron.—Production of pig-iron has been increased by putting into operation two extra furnaces, one on Cleveland pig-iron and one on hematite iron. This makes the total number blowing on the North-East Coast 76, of which 34 are making Cleveland pig-iron, 28 are producing hematite iron, and 14 are manufacturing basic, spiegel and other special irons.

Coke.—Supply of coke continues more than ample, but values are well maintained. Export business shows some little improvement, demand being chiefly from Scandinavia. For shipment, both beehive and patent oven remain at 42*s.* 6*d.*, and gashouse product is in the neighbourhood of 31*s.* All qualities of blast-furnace coke are in very good request for local use. Average descriptions continue to command the fixed maximum of 28*s.* at the ovens, and low phosphorus sorts remain at the limitation figure of 30*s.* 6*d.* at the ovens.

Foreign Ore.—Rather better deliveries of foreign ore are reported, and a few contracts are made from time to time. It is gratifying to have the assurance that consumers are receiving sufficient quantities to keep going. Distribution, under official control, is made according to priority of need.

Manufactured Iron and Steel.—To cope with the huge requirements of the Government and the heavy and growing needs of the shipyards, producers of manufactured iron and steel are kept working at high pressure, and are unable to entertain ordinary commercial inquiries. Pressure for delivery of steel shipbuilding material is particularly pronounced, and every effort is exerted to expedite output. Prices of all descriptions of finished iron and steel are very stiff. The following are among the principal market quotations to home customers:—Common iron bars, 13*l.* 15*s.*; best bars, 14*l.* 2*s.* 6*d.*; best best bars, 14*l.* 10*s.*; iron ship plates, 15*l.* 10*s.*; iron ship angles, 13*l.* 15*s.*; iron ship rivets, 18*l.*; packing iron and steel (parallel), 13*l.* 10*s.*; packing iron and steel (tapered), 15*l.* 15*s.*; steel bars (no test), 14*l.* 10*s.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel ship rivets, 20*l.* and upward; steel boiler plates, 12*l.* 10*s.*; steel joists, 11*l.* 2*s.* 6*d.*; steel strip, 15*l.* 10*s.*; and heavy sections of steel rails, 10*l.* 17*s.* 6*d.*

CONTRACTS.—The progress of the Lymn Producer Gas and By-Products Plants during the last twelve months is shown by the following contracts: A 260-ton (coal per day) plant is now being erected by the South Manchuria Railway Company; a 100-ton plant by the Monongahela Valley Company, West Virginia, U.S.A.; a 100-ton plant by the Westmoreland Coal Company, of Philadelphia, U.S.A.; a 40-ton plant (a repeat order) by the Hoffmann Manufacturing Company, Limited, Chelmsford, England; and a 40-ton plant for the Lilleshall Company, of Oakengates. All of these should come into operation during the present year. The system is owned by the Lymn Chemical Engineering Company, Limited., 40, Westminster Palace Gardens, London, S.W.1.

RATE OF COOLING OF COKE.—Some comparative experiments on the time which hot coke takes in cooling have been made at the Technical High School of Breslau, on specimens of coke from the various coal districts of Germany, on the Rhine, the Ruhr, the Saar, in Saxony and in Upper and Lower Silesia. The specimens were heated up to 800 deg. C. in an electric furnace under exclusion of the air, and cooling curves were obtained with the aid of thermocouples. The specimens were small, about 15 cm. in dimensions, and the experiments cannot claim more than a comparative value. All the curves were very similar; the cooling of the inner layers of the coke took as many minutes as the cooling of the surface layers took in seconds, *e.g.*, from 30 seconds to 40 seconds to cool from 800 deg. C. down to ordinary temperature.

NOTES FROM THE SOUTH-WEST.

Cardiff.—Very idle conditions have prevailed on the market this week. The shortage in the supply of tonnage shows no sign of amelioration, and many collieries are reported idle through lack of empties. To some extent the increased inland demand for certain classes of South Wales coals is giving pits temporary relief, but on the average position the effect of these inland sales has been very slight. Pitwood is steady at between 60*s.* 6*d.* and 61*s.* 6*d.* In other directions there has been no feature, and current fixed prices remain unaltered.

Newport.—The arrangements under the inland reorganisation scheme are now fairly well in hand, and the new instructions from the Controller have slightly increased the quantity of coal required from South Wales for consumption in distant areas. Where transport facilities have been available this increased demand for inland consumption has eased the position of Newport coals, but only to a small extent. Pitwood is practically unchanged on the basis of about 61*s.*

Colliery Officials' Strike Threat.—As already announced, the lower-grade colliery officials who are members of the South Wales and Monmouthshire Colliery Examiners' Association have tendered notices to terminate contracts, and these notices will expire at the end of the month. The most difficult issue appears to be over the question of the recognition of the association by the Monmouthshire and South Wales Coalowners' Association, and the difficulty is accentuated by reason of the fact that the coalowners who are members of the association have always reserved to themselves the right of dealing with their own official staffs without interference from that body. On Wednesday a deputation, which included the chairman, vice-chairman and secretary of the association, waited upon the Coal Controller to explain the attitude which has hitherto been adopted in regard to the examiners. A special meeting of the owners is being convened in order to consider the somewhat serious situation which has now arisen.

THE CHEPSTOW SHIPBUILDING YARD.—The Standard Shipbuilding and Engineering Company has received intimation that the Government desire to occupy its yard at Chepstow. A large number of soldiers are now at work on the site. It is stated that the Government intend also to take a further site at Chepstow for the putting down of a shipbuilding yard.

DIRECTOR OF ENGINEERING WORK.—We are informed that the Deputy-Controller for Auxiliary Shipbuilding at the Admiralty has appointed Lieutenant-Colonel J. Mitchell Moncrieff to be Director of Engineering Work, to deal with all civil engineering questions which may arise in connection with the department. Colonel Moncrieff is a member of the Institution of Civil Engineers and has had an extensive practice as consulting engineer for docks, shipyards, and river and harbour developments.

COAL PRICES.—The Board of Trade has issued further orders, dated the 11th and 12th inst., dealing with the retail prices of house coal during the war. Communications concerning these orders should be addressed to the Controller of Coal Mines, Board of Trade, 8, Richmond Terrace, Whitehall, S.W. 1. An order has been issued dealing with the situation in regard to Scotland, by Mr. Robert Munro, H.M. Secretary for Scotland, Scottish Office, Whitehall.

THE GERMAN RAILWAY WAGON INDUSTRY.—Negotiations have commenced between the Prussian State Railway Department and the railway carriage factories in regard to deliveries for the half of the railway budget year 1917–18, from April 1 to September 30, 1918. The increase in the rolling-stock principally applies to goods wagons. The negotiations are impeded by the fact that the works are unable to state, with any accuracy, their capacity on account of the difficulty in obtaining raw material. The works are employed to the full extent of their capacity, and some of the works are much behindhand with their former contracts. On account of the increase in the cost of manufacture, a further addition to the contracted price, which covered some three years, if we are not mistaken, is anticipated.

HARDENING OF ALUMINIUM BRONZES.—Aluminium bronzes can be improved by thermal treatment. When they contain less than 7 per cent. of copper, the thermal treatment will not affect the properties much, according to the *Giesserei Zeitung* for June 1, 1917. Higher-grade bronzes can be hardened, however, and by the further addition of iron, silicon and other elements the mechanical properties of the alloys can be much varied. Thus, for instance, bronzes can be prepared having a Brinell hardness of 100 without being brittle. An aluminium bronze, resembling in its mechanical properties a 0.35 carbon Swedish steel, was given hardness values ranging from 100 up to 260 by various thermal treatments; such bronzes of great hardness will answer as bearing metals even for high speeds. The following figures are given as to the properties of a 10 per cent. aluminium bronze containing some titanium, the percentage of which is not stated; the figures refer to the original alloy as cast, to the quenched bronze, and to the bronze after thermal treatment at different temperatures:—Limit of elasticity in kilograms per square centimetre: 9.6, 19.8, 27.7 to 19.2; tensile strength in kilograms per square centimetre: 51.8, 73.6, 67.7 to 64; elongation in per cent.: 19.5, 1.0, 5.5. to 1.4; contraction of area in per cent.: 33.7, 0.8, 9 to 18.5; Brinell hardness: 100, 262, 158 to 140.

THE BRIQUETTING OF IRON ORE: PLANT FOR THE GREENAWALT PROCESS.

(For Description, see Page 299.)

Fig. 6.

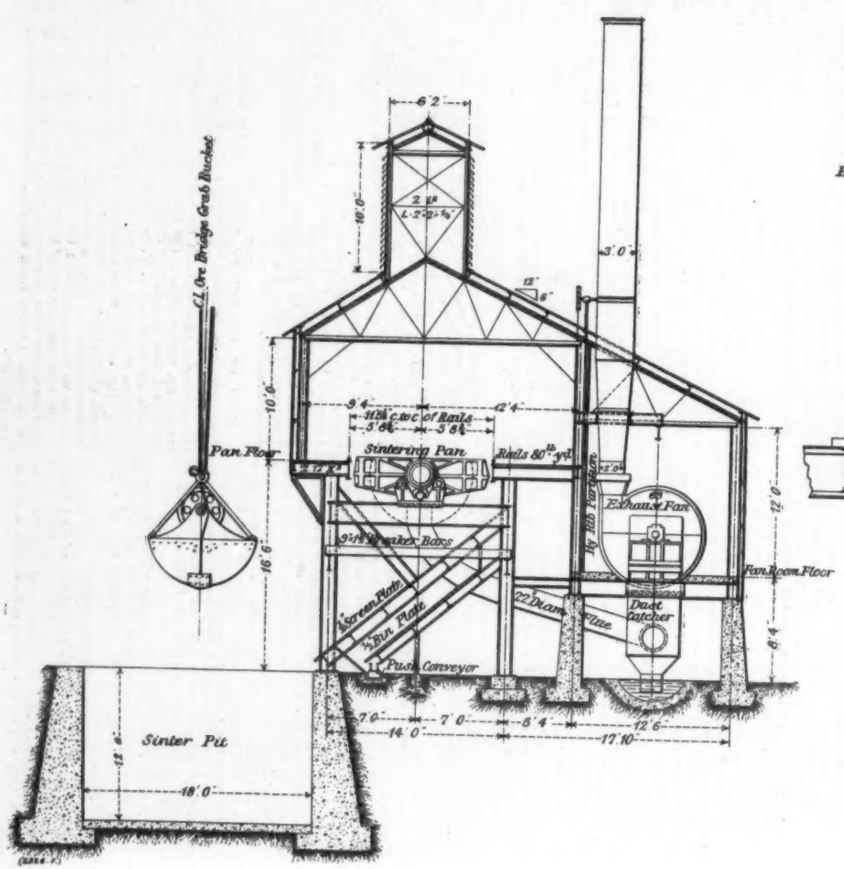
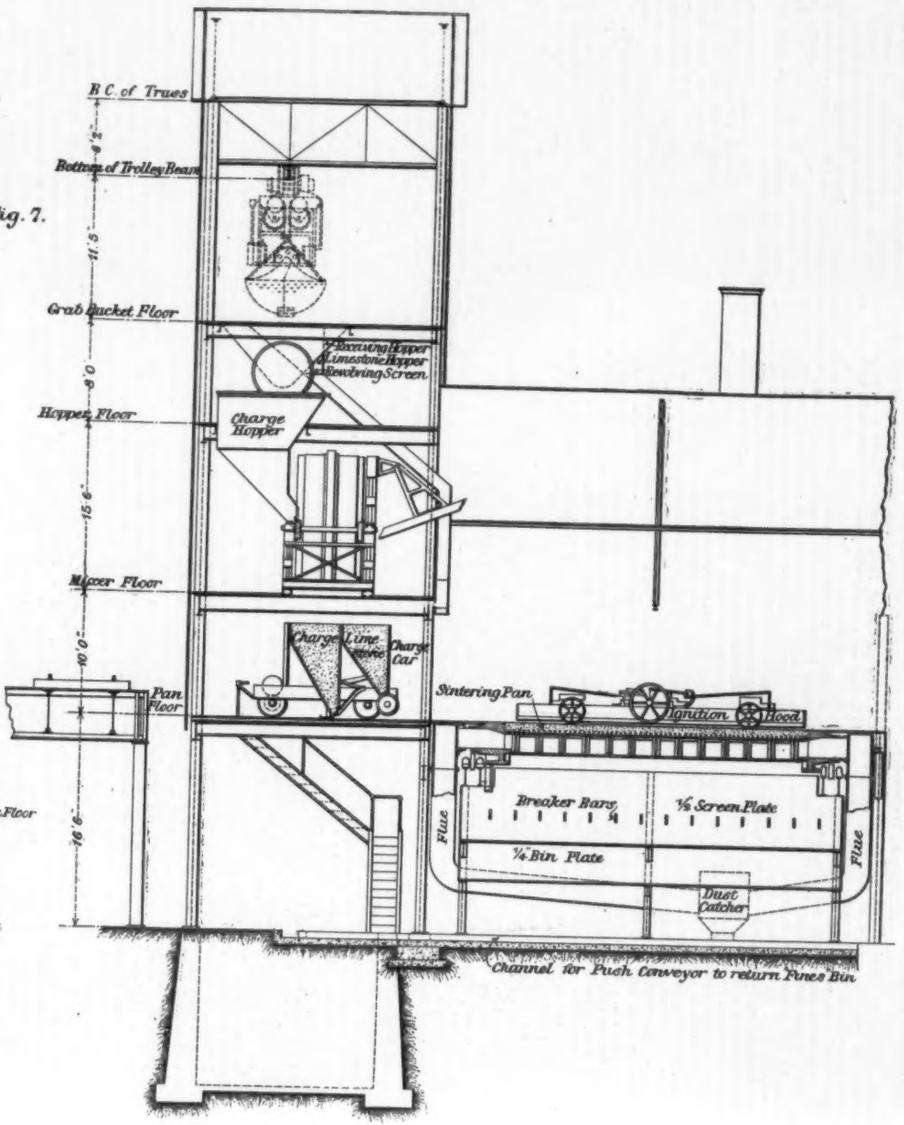


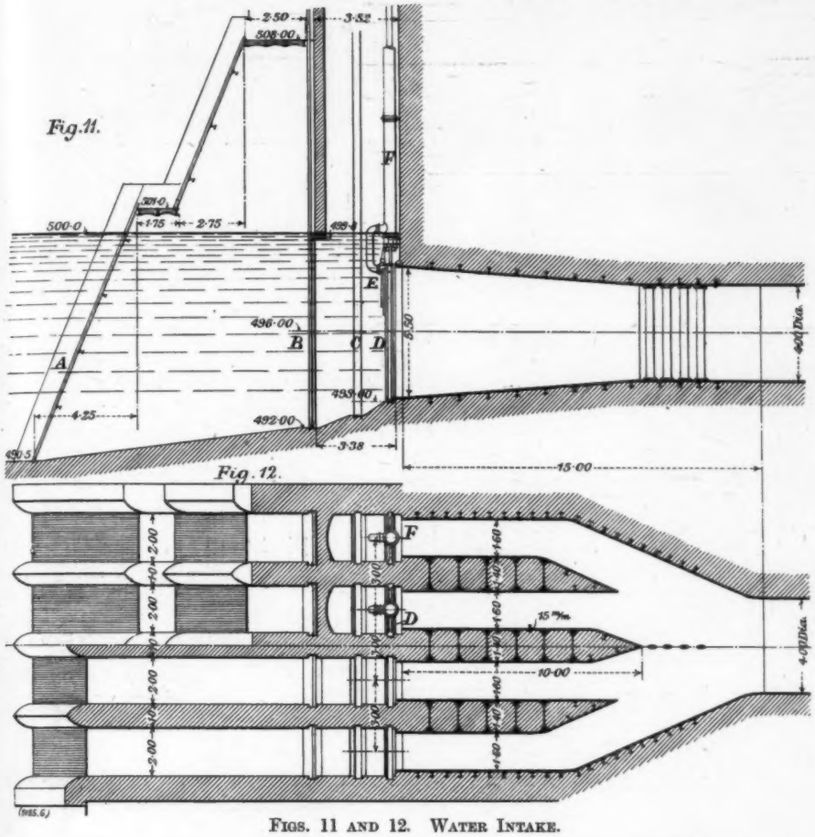
Fig. 7.



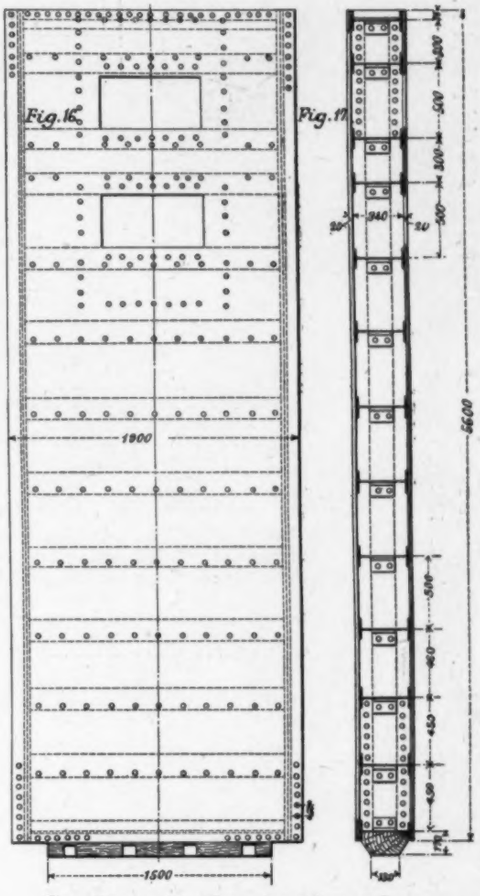
THE WORKS OF THE BARCELONA TRACTION, LIGHT AND POWER COMPANY.

MESSRS. ESCHER WYSS AND CO., ENGINEERS, ZURICH.

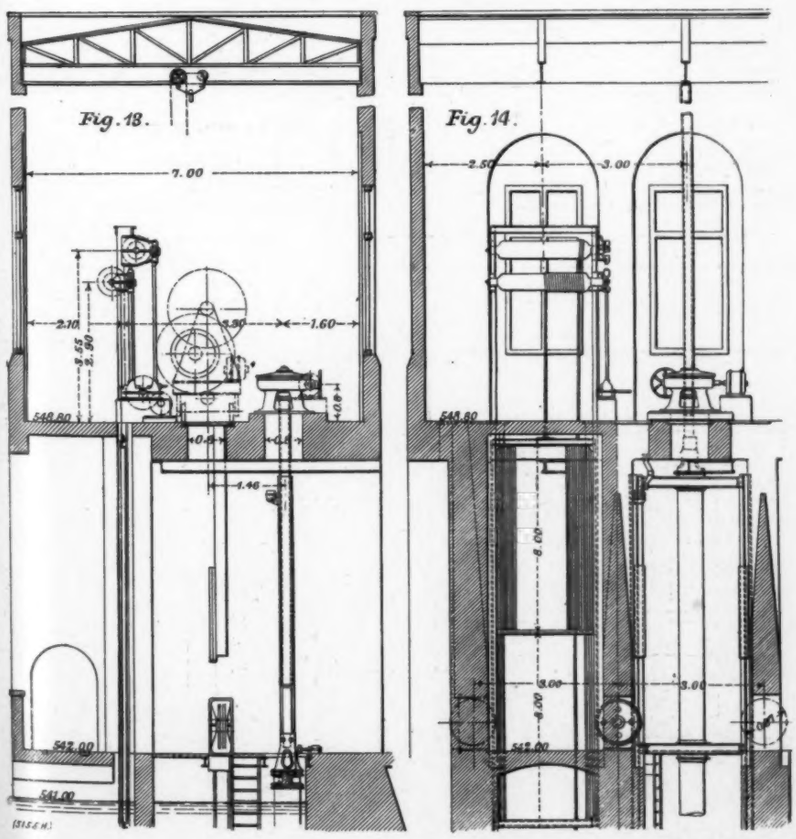
(*For Description, see Page 293.*)

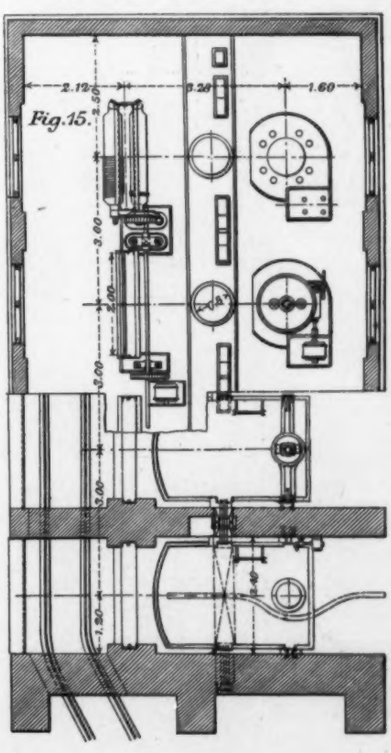


FIGS. 11 AND 12. WATER INTAKE.



FIGS. 16 AND 17. EMERGENCY SLUICE GATES.





FIGS. 13 TO 15. GEAR FOR OPERATING SLUICE GATES.

(*To face page 294.*)

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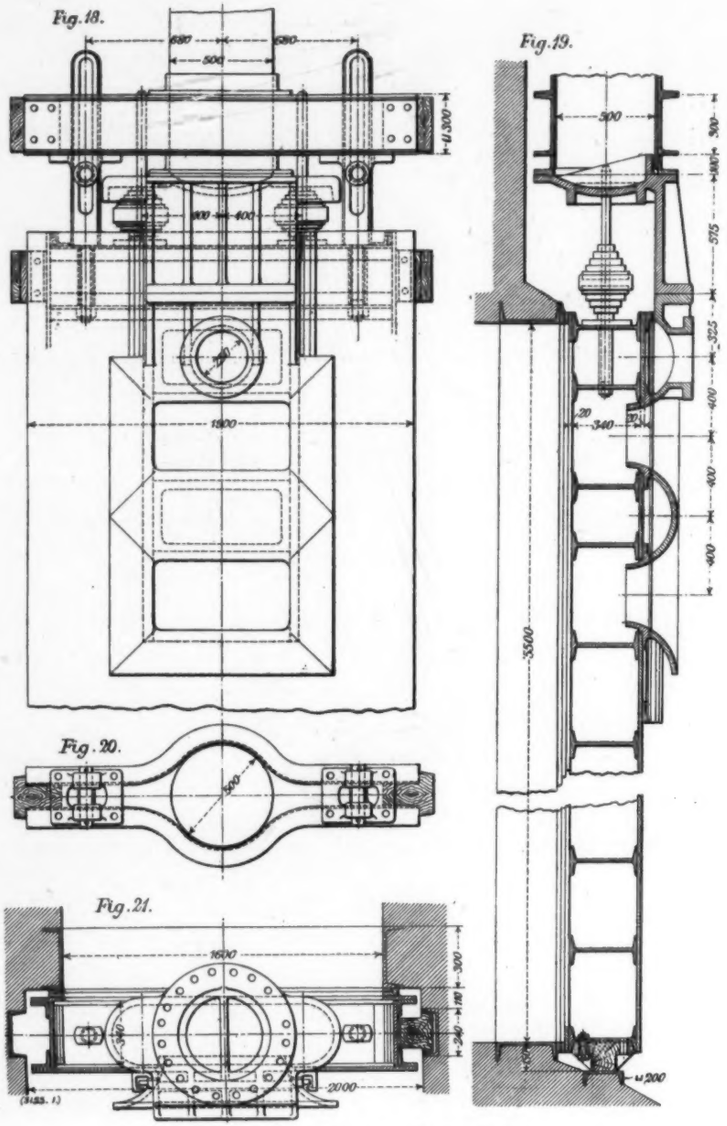
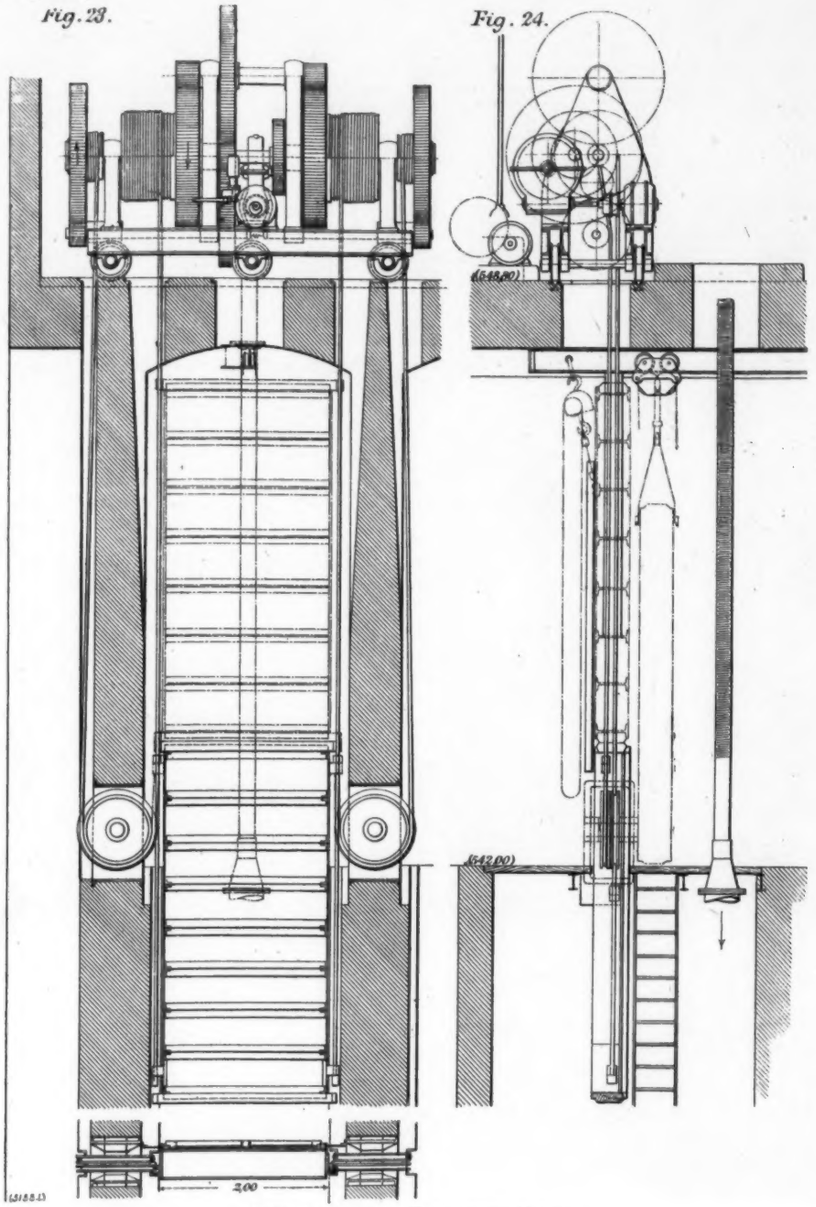
(*For Description, see Page* 293.)



FIGS. 18 TO 21. DETAILS OF SLUICE GATES.



FIGS. 23 AND 24. EMERGENCY GATES.

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(*For Description, see Page* 293.)

Fig.25

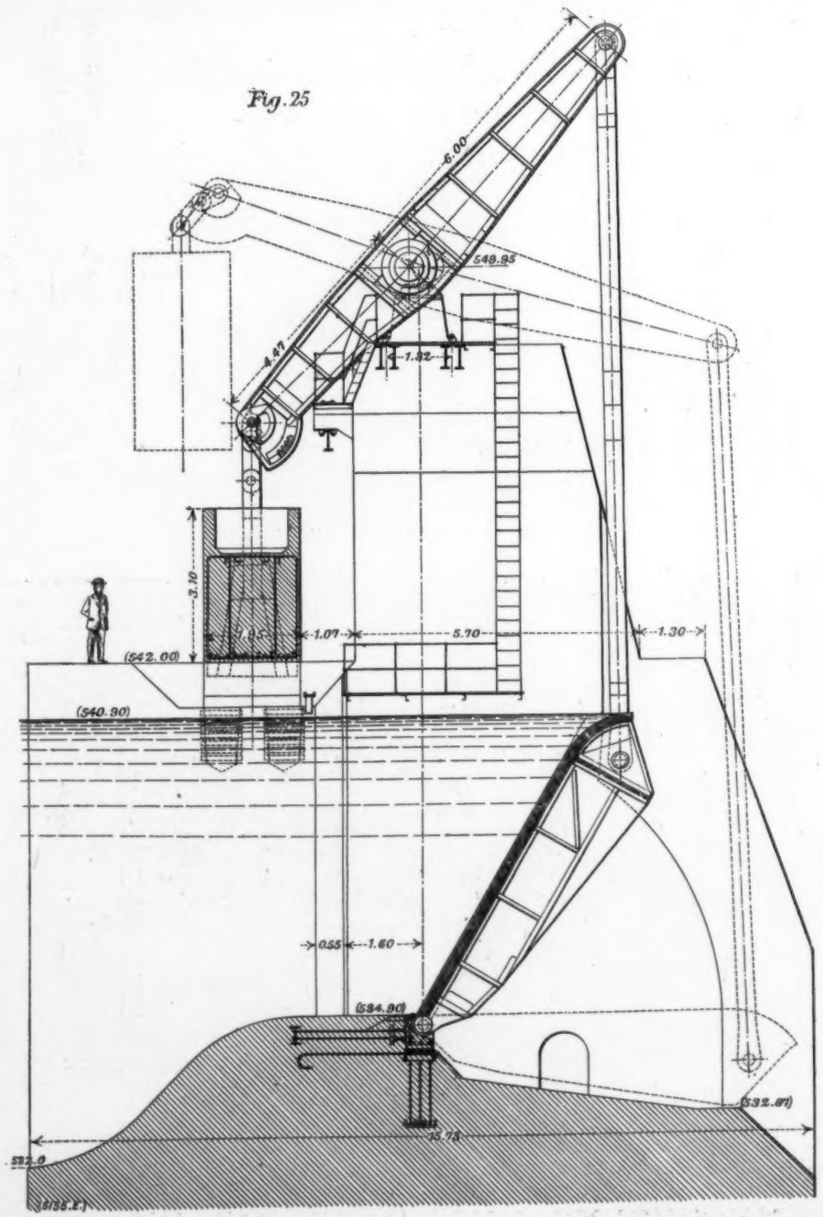
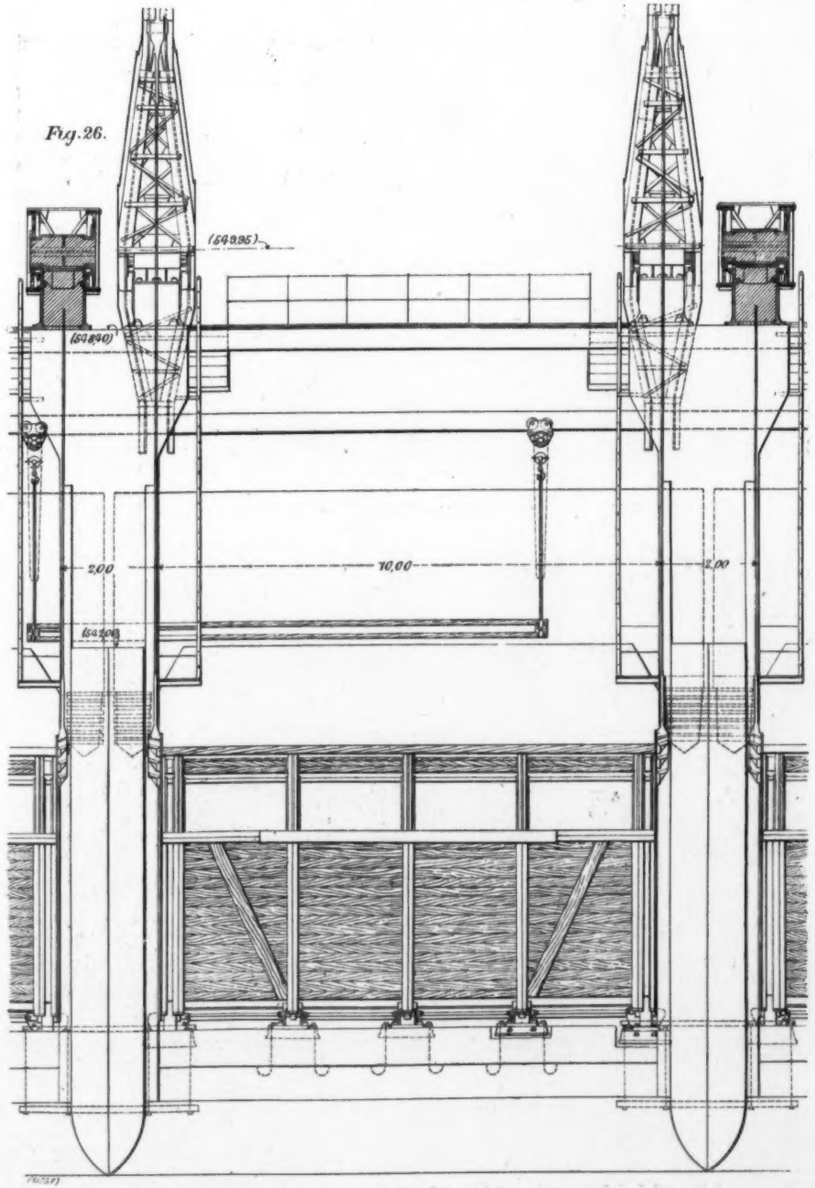


Fig.26.



FIGS. 25 AND 26. AUTOMATIC DOUBLE-LEVER OVERFLOW WEIR GATES.

THE WORKS OF THE BARCELONA TRACTION, LIGHT AND POWER COMPANY.

MESSRS. ESCHER WYSS AND CO., ENGINEERS, ZURICH.

(*For Description, see Page* 293.)

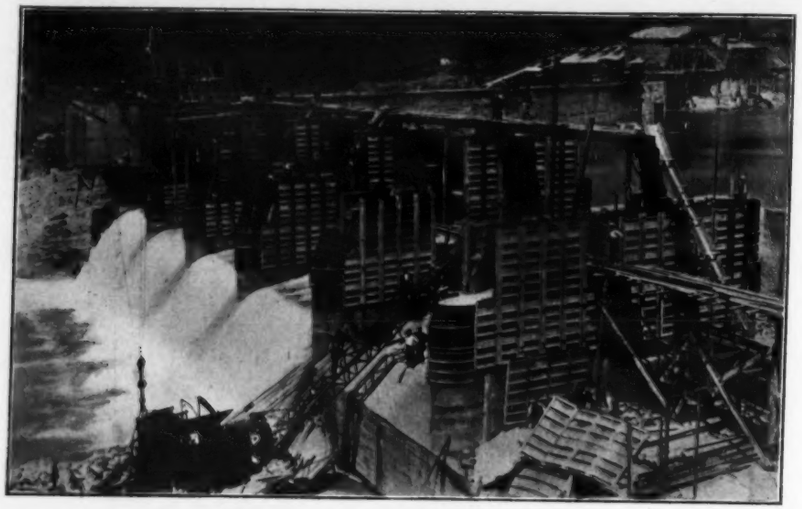


FIG. 27. WEIR IN COURSE OF CONSTRUCTION.

FIG. 28. VIEW OF AUTOMATIC WEIR GATES NOS. 1 AND 2.

FIG. 29. DAM OVERFLOW AT WEIR AND PUMP-HOUSE.

FIG. 30. ROUGH SCREENING INSTALLATION.

(*To face page* 295.)

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Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—8963 and 8368 GERRARD.

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With Four One-Page Plates of the WORKS OF THE BARCELONA TRACTION, LIGHT AND POWER COMPANY.

NOTICES OF MEETINGS.

THE ASSOCIATION OF SUPERVISING ELECTRICIANS.—Tuesday, September 25, at 7.15 p.m., at St. Bride's Institute, Bride Lane, E.C. Presidential Address by Mr. J. S. Highfield, M.Inst.C.E., M.I.E.E.

THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.—Thursday, September 27, at 3 p.m., at the Queen's Hotel, Leeds, when the following paper will be read:—A Note on "The Co-Relation of Seams in the West and South Yorkshire Areas," by Professor P. R. Kendall, M.A. F.G.S. There will also be a discussion on "The Areas of Deposition of the Coalfields of North-Western Europe," introduced by Mr. G. Blake Walker.

THE INSTITUTION OF LOCOMOTIVE ENGINEERS, LONDON, INCORPORATED.—Thursday, September 27, at 7 p.m., at Caxton Hall, Westminster. Paper by Mr. J. F. Gavins, Member of Council, "Standard Locomotives for British Railways."

THE ROYAL SANITARY INSTITUTE.—Saturday, September 29, at 10.30 a.m., at the Town Hall, Chatham, when discussions will take place on:—"Some Points in Epidemic Cerebro-Spinal Meningitis," by Surgeon A. G. L. Reade, R.N.V.R., Asst. M.O., L.C.C. "Some Aspects of the Housing Problem," by Mr. J. Holroyde, F.R.C.S.E., D.P.H., M.O.H. Chatham. "Public Abattoirs," by Mr. R. L. Honey, F.S.I., Asst. Borough Surveyor, Chatham. The chair will be taken at 10.30 a.m. by Professor H. R. Kenwood, M.B., D.P.H., Lieut.-Colonel R.A.M.C., Member of Council.

NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal from 6d. to 8d. per copy. This increase dated from and included the issue of Friday, March 16. The change will not apply to unexpired subscriptions.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

ENGINEERING.

FRIDAY, SEPTEMBER 21, 1917.

TERMS OF CONTRACTS: ESTABLISHMENT CHARGES AND PROFIT.

WE have had many articles on the subject of terms of contracts, which must be drafted, not only in view of the existing war conditions, but of the peculiar situation, which must continue after the achievement of victory. We have consistently disapproved of the practice of contracts being arranged on the basis of payment for material and wages, plus a percentage for establishment charges and profits, because this system constitutes a premium on inefficiency. The greater the laxity from ordering material under the most favourable conditions, and the greater the inefficiency in organising and utilising labour, the greater will be the sum received for establishment charges and profit. Normally, the old method of a comprehensive contract price has much to commend it, but now conditions are, and must for some years continue to be, abnormal. At the present time, with more than 5,000 factories controlled, and with all establishments compelled to distribute their orders for material where they can be most expeditiously executed, and while the Government alone are the arbiters as to labour remuneration, there is neither effective control nor fixity of rates, so far as the great producing companies are concerned. It is therefore impossible for the firms to tender for work with any guarantee that the basic prices for material and labour will be operative throughout the period covered by the contract; and this being so, the only equitable way, not only for Government contracts, but for others, is to arrive at an arrangement which will be fair to seller and buyer alike, and will yet ensure a high degree of efficiency, develop organisation, and provide a stimulus towards increased producing capacity.

The onus of evolving a scheme rests upon the purchasing departments of the Government, because they have absorbed, for State service, practically all producing establishments. No firm can refuse to undertake Government work; nor have they much latitude in the ordering of material, because it is of the utmost importance that such subcontracting should be done with less regard to the ordinary market practice of securing the most favourable terms than to the ensurance of the earliest delivery. It is the same with labour. All conditions of employment are now determined between the trade unions and the Government labour departments. At the same time it is of vital consequence, not only for the achievement of economy in national expenditure, but for continuously stimulating the application of efficient principles of production, that the works management shall be encouraged to ensure effective working conditions. It cannot be said that the present method of payment in force by the Contract Department of the Admiralty has had this effect. In the early stages of the war fixed contract prices were possible, and in most cases were obtained, but very shortly afterwards, owing to the great increase of Admiralty work, this method had to be departed from because of the difficulty of getting fixed prices from some of the contractors, who not only were new to the work they were called upon to undertake, but who, along with the regular Admiralty contractors, had to contend with the growing instability of the markets for labour and material. The position in this respect has now become so acute that, as we have said, it is quite impossible to get—and unreasonable to expect—a contractor to name a present-day price which will reasonably protect him against future increases in these markets. Accordingly, the "time and line" method was adopted, with all the evils and drawbacks to which, in a former article, we alluded. The procedure under this system was to pay contractors for labour and materials the exact amount expended, to ascertain through accountants appointed by the Admiralty the establishment charges involved, and, further, to allow a fixed percentage for profit. In some cases the amounts payable for establishment charges were calculated on a percentage basis, but in the final stages contractors were asked to submit an inclusive price for all purposes, and in the end, if this price were lower than the actual disbursements, the contractor suffered; whereas if the tender proved to be more than the actual costs the latter were relied upon in the payments made. This one-sided arrangement has proved very unsatisfactory, as may well be supposed, and when the new Department of Auxiliary Shipbuilding was organised, including in its composition many who were formerly contractors, sound practical experience was concentrated on the evolution of new terms of contract which would meet the fluctuating conditions which we have stated. It will be seen, as we have time and again pointed out, that conflicting conditions require drastic experiments, and we are glad to record the success of a system introduced by the Merchant Shipbuilding Advisory Committee in connection with the terms of contracts for the construction of the standard ships and engines, a principle which the Department of Auxiliary Shipbuilding is now proposing to extend to all the other classes of craft being built under its supervision.

The principle adopted in evolving these new terms of contract was that establishment charges had a close affinity to profits. In former articles we have drawn distinction between an admirably equipped and organised factory and one where efficient principles of production were not understood or were not applied. We might make the distinction that establishment charges cover the work of the mental force in a factory. Where brain power is utilised, its contribution to the fulfilment of a contract must be recognised, and this is most appropriately done under the heading of "establishment charges." It is not only a case of utilising mechanism for augmenting the effort of labour, but of so organising labour as to secure the maximum output for the minimum wage cost, without intensifying physical or muscular effort. There is thus demanded a definite remuneration, because the effect is to reduce the labour as well as the material cost, and anything which tends to depreciate the influence of this brain power is inimical not only to present-day efficiency, but to future development along sound industrial and economical lines.

It will be admitted that profits on an ordinary contract job are largely influenced by the effectiveness of this mental effort towards efficiency, so that it is difficult to dissociate establishment charges

(To face page 293.)

from profit. Indeed, we might go further, and claim that profits on ordinary contracts, effected through tender, are dependent on the work which is supposed to be paid for through establishment charges. The Department of the Deputy-Controller of Auxiliary Shipbuilding—largely through the consistent advocacy of Mr. W. Rowan Thomson, Director of Machinery, and a member of the Merchant Shipbuilding Advisory Committee—has therefore decided that in contracts these two items shall be regarded as one, and, in order to remove that premium on inefficiency consequent on the payment for these items by a percentage on the actual cost of material and wages, the establishment charges and profit are to be paid for by a lump sum. We have thus that stimulating basis of contract for which we have contended in previous articles.

The equity of the arrangements as between the Government and the contractors depends, of course, on a fair sum being named for establishment charges and profit for each type of ship built, or each design of machinery constructed; but the attainment of equitable terms is simplified by the large number of ships of each type ordered. Where there is, as we hope there will be in the future, an approach to standardisation, it will be possible to get from many firms a definite tender, with the estimated cost for material, wages, establishment charges and profit. From these competitive tenders it will be easy for an experienced authority to arrive at a fair mean sum for charges and profit. Moreover, it should not be difficult for the Admiralty, with an expert staff, to get out quantities and wage values in order to check the tenders submitted by the various firms. This done, the procedure would be that of giving to each firm a sum to cover charges and profit, permitting them to proceed to the purchase of material and the utilisation of labour under the most advantageous conditions. Ultimately accountants would check the disbursements under the heads of both material and labour, in order to ascertain that the best has been done in the interests of the buyer, and, finally, to deduct from or add to the amount paid in instalments, on behalf of the Government, for the execution of the work.

The contention may be made that this system of an equal sum for establishment charges and profit does not reward the firm having a really efficient system of establishment organisation. But a little investigation of the conditions will show that the firm applying sound principles of production will turn out the work much more quickly, and, consequently, with a fixed sum for charges and profit on a larger turnover, will gain a higher annual return on their plant. This, after all, is the principal aim to be achieved, not only in our present war emergency, but under the future stringent competition. It may be objected that there is no incentive to the contractor to buy his material in the cheapest market. This objection, however, does not carry weight at the present time. The concentration of orders in the "cheapest market" would tend to excessive demand in such market, with the result that supplies would be delayed, and time is at present the important element in all contracts. Moreover, prices are so completely controlled that there is not the same opportunity for firms to secure an advantage in the ordering of materials under favourable conditions. The Government Departments, moreover, have an important say in the distribution of sub-contracts, so that the objection is applicable more against the future application of the principle than against present enforcement.

The system, we think, is admirably suited even for private contracts, especially in view of the unsettled conditions which must prevail after the war. In 1914 many orders were placed, not only for ships, but for all mechanical productions, under favourable conditions for the buyers. The intervention of the war has made it impossible to execute contracts under such conditions. The prevailing economic situation, which must continue for some years, renders it impracticable for any firm to carry out the contracts on pre-war terms, and it should be possible to apply the method to which we have referred in connection with the fulfilment not only of pre-war contracts, but of other contracts made now. It is true that there will not be the same multiplicity of orders for ships of a given type as is the case at present with standard merchant ships, mine sweepers, mine layers, and the like. But, as a rule, a shipowner invites a number of firms to submit tenders, and through this multiplicity of data it will be possible to strike a fairly equitable mean as a sum to be paid for establishment charges and profits.

It is important that there should be no dubiety as to what is embraced in the term "establishment charges"; and in the contracts for the standard ships and standard engines this has been met by clearly defining what is embraced under "material" and under "wages," all other disbursements being regarded as establishment charges. In connection with the supply of machinery, for instance, the procedure is that the expression "materials" shall include all materials and stores used in connection with the construction of the engines, boilers and machinery, the outfitting, steaming and sea trials, and all moneys expended by the contractors in or about the procuring or providing of the materials for the complete construction, fitting, furnishing and delivery of the engines, boilers and machinery. Materials manufactured or worked in the contractor's shop are to be charged at market rates current during the progress of the contract. Where the contractor supplies material from his own stocks or contracts, payment is to be made at current market rates. All goods are to be charged at invoice net cash prices. Harbour dues, towage, cartage and haulage costs are to be charged direct to the contract. Scrap material is to be the property of the contractor. The cost of any work done upon any materials which may prove to be defective is to be charged to the contract. Charges for the use of cranes or sheerlegs for the shipment of machinery are to be at the rates ordinarily charged by the contractors. Survey fees, insurance premiums for marine policy covering fire and other risks and royalties paid by the contractor are to be charged to the contract. All drawings, patterns, tools and accessories necessary for the execution of the work remain the property of the contractor. Here it may be interpolated that objection may be taken to the charge against the contract for work done on material which may prove to be defective, but under normal conditions this is always the case. The contractor, in ordinary times, charges such work against his establishment expenses, or directly against the job itself. The reason for such work requiring to be paid for, although unremunerative, corresponds exactly to that for a fire risk, and every contractor, while taking care to reduce it as far as possible, insures himself against the contingency in preparing his tender.

Under "labour" the work includes all wages paid to workmen and draughtsmen who book their time direct to the contract, together with outworking and travelling expenses, wages of pattern-makers making new patterns or altering or repairing existing patterns. There is included also the cost of indirect labour, namely, the wages of foremen, time-keepers, store-keepers, piece and bonus clerks, cranemen, slingers, and sundry shop labour, together with cost of national insurance and workmen's compensation. These indirect costs are distributed proportionately over the work passing through the contractor's shop as a percentage on direct labour.

One advantage, under present war conditions, of this system is that it is possible during the progress of the contract to pay instalments with as much approximation to accuracy as under a fixed contract by tender. The invoices for material and the labour charges are available at any given time—for instance, when instalments are due—and the payment for establishment charges and profit can be divided proportionately. When a contract has been executed, the examination of the books by accountants for the verification of the cost of wages and material will show only a small sum to be paid by one or other party. At present there is immense confusion, owing to the difficulty of making adjustments on contracts where percentages for establishment charges and profit are arranged for, and thus the Government owe many firms hundreds of thousands of pounds, which prevents annual accounts being produced to conform to the Companies' Acts. Even the elimination of this confusion is a strong recommendation of the terms of contract now arranged, and we commend their consideration not only to the Admiralty in connection with the fighting ships as well as auxiliary ships, but to all shipowners, and, indeed, to all buyers of mechanical productions, either now or in the years immediately following the attainment of victory.

THE WORK OF THE ROAD BOARD.

In view of the limitations under which their work has had to be carried out, it is not surprising that the Report of the Road Board* just issued is a far less interesting document than any one of its predecessors. The revenue previously derived from the petrol and carriage duties has now been diverted to meet other requirements of greater urgency, so that the receipts during the past year have consisted wholly of the interest payments on investments and loans, amounting in all to 152,902*l.*, or rather less than one-tenth of the receipts in 1915, which came to a total of 1,620,974*l.* Fortunately the recommendation of the Retrenchment Committee that the Board should, for the period of the war, discontinue all contributions in aid of highway improvements has not been acted on. A sudden cessation of these payments would have involved serious losses, and in many cases would have resulted in much work having to be done twice over. The total expenditure during the year has been 445,927*l.*, as against 1,386,173*l.* in 1915, and 609,244*l.* in 1916. Most of last year's expenditure was made on account of work already in progress, Parliament having fixed a limit of 200,000*l.* to the amount of new loans the Board was authorised to make during the twelvemonth.

Up to date the total receipts of the Road Board from its inauguration have amounted to 7,393,097*l.*, and its outlay to 3,663,497*l.* Both sums are, no doubt, large in absolute value, but they are unfortunately very small relatively to the expenditure which must ultimately be made on our highways if these are to be put in condition to carry modern road traffic.

This question is dealt with in a memorandum to the Reconstruction Committee, which is published as an appendix to the report under review. In this note the Board states that at least 15,000 miles out of the 152,000 miles of roads in England and Wales stand in urgent need of reconstruction, as no mere surface treatment would fit them for their normal traffic. The cost of this work is estimated at 2,000*l.* a mile, making a total of 30,000,000*l.* in all. In addition, a considerable mileage of new roads or widenings, estimated to cost 5,000,000*l.* in all, should also be undertaken. Still more urgent, perhaps, is the necessity for strengthening many bridges over railways and canals, which in their present condition are suitable only for relatively light loads. In accordance with a recent legal decision the onus of these improvements must be carried by the public, and not by the railway and canal proprietors. In Middlesex alone there are 22 bridges which are now inadequate to the requirements of the day, and long stretches of roadway thus fail to carry their due proportion of heavy traffic. The total cost of such reconstructions as are now urgent under this heading is put at, at least, 7,000,000*l.* Much more could also be usefully expended in the construction of new approach roads and by-pass roads in the Metropolitan area, and in other densely-populated districts. In fact proposals have already been definitely formulated for 130 miles of such works in the Metropolitan area alone, which, if undertaken, will cost from 10,000,000*l.* to 15,000,000*l.* to execute. In reporting on these to the Local Government Board, the Road Board observes that such schemes can hardly be usefully discussed until some suitable financial arrangements have been made. The highway authorities are not prepared to do this on their own initiative. Indeed they are disinclined to undertake even the reconstruction of those roads of which the maintenance costs are now excessive, although this is a first essential to any reduction on the annual upkeep charges. These have steadily risen throughout the country for many years past, the total for England and Wales being 17,500,000*l.* in 1914–15, which is

* "Seventh Annual Report of the Road Board." H.M. Stationery Office. Price 6d.

equivalent to 114.6*d.* per head of the population and to 19.6*d.* on the assessable value.

Though, as stated, the normal activities of the Board have been much circumscribed by the restrictions imposed by the war, its experienced staff has been able to give most valuable assistance to the naval and military authorities. To meet the requirements of the Admiralty, the Army and the Ministry of Munitions it has been necessary to make a considerable mileage of new roads, and to strengthen and widen others. These works have been carried out to specifications prepared by the Road Board, and under its supervision. It has, moreover, acted as assessor in fixing the payments due to the local authorities for damage done by "extraordinary" military traffic. The sum total spent under the foregoing heads has, so far, amounted to 2,760,141*l.* The Road Board has also helped in France, where invaluable work is now being done behind the lines by its former chief engineer and manager, Mr. (now Brigadier-General) H. P. Maybury, C.B., whose place at home has been taken by Mr. J. S. Killick, whose services have been lent by the Hertfordshire County Council.

EDUCATIONAL AUTHORITIES AND INDUSTRIAL TRAINING.

THE subject of the educational needs of the present and near future has recently engaged the most serious attention, not only of professional educationalists, but also of the leaders of thought and action in the spheres of commerce and industry, and the broad-minded proposals of the President of the Board of Education have still further stimulated interest in this most essential subject. While it may be said with truth that the whole scheme of education stands in need of reconsideration in the light of present-day requirements, it is undoubtedly a fact that the most urgent need of the moment lies in the provision of the means to increase the individual and collective efficiency of the worker in order to meet the increasing demands of the present and near future, and at the same time provide such elements in his education as may teach him to appreciate at their true value the responsibilities and privileges of citizenship. To give full effect to this ideal requires that a start be made in the elementary schools, and it is of the utmost importance that this be undertaken at the earliest possible moment, but much can and must be done to provide corresponding educational facilities for those who have gone beyond the elementary school stage, either in years or in educational attainment.

In the matter of the provision of these facilities, the schemes of technical and trade classes organised by the London County Council and the Glasgow School Board respectively are of great interest, and worthy the consideration of all interested in the commercial and industrial future of the country. In the case of both cities it has been clearly recognised that the success of these classes depends to a very large extent upon the goodwill and active co-operation of employers of labour, and in both cases this has been actively sought and in large measure obtained. In this connection it is of interest to note that in the case of some large employers of labour in London classes have been held for their employees within the works—tuition and any apparatus required being provided by the London County Council. This shows a spirit alike creditable to the firms concerned and to the London County Council, but while excellent results might be secured in the teaching of general subjects, the method hardly seems adequate for the teaching of trade subjects, owing to the fact that outside teachers cannot be familiar with the latest trade practices.

It must of course be borne in mind that there are essential differences in the educational requirements of London and Glasgow, for whereas London is the centre of commercial rather than manufacturing activity, Glasgow is the centre of the vast industrial and manufacturing area embracing the Clyde shipyards and engine works, and the West of Scotland generally. It is therefore natural that technical and trade classes bearing upon the staple industries of shipbuilding and engineering and their subsidiary branches should be proportionately more numerous in comparison to purely commercial subjects in the Glasgow scheme than in that of the London County Council. Under the London County Council scheme a boy can decide upon a trade and commence at the age of 13 or 14 a specialised course of two or three years, which is intended to fit him for starting his apprenticeship in the shops. He then proceeds to the evening class course in technical and trade subjects at a junior institution, and passes on to a Polytechnic or Technical Institute to complete his course, and, if desired, to work for the degree of B.Sc. The courses at the junior institutions and polytechnics are affiliated, and thus provide a continuous course of instruction. Provision is made for approved trade apprentices attending their appropriate trade classes, and a scheme of fees graduated in accordance with the earnings of the student is a most admirable feature of this arrangement, while a further concession is made to meet the case of an unemployed student, whereby he may attend the classes free. In London there are 250 institutions for the evening class instruction of students now open and providing classes to meet the requirements of those engaged in industry and commerce, *e.g.*, engineering, building and chemical trades on the one hand, and shipping, railway, banking and insurance on the other. It is encouraging to note that during the conduct of the war, and the disturbance of every form of social life, there has been a great improvement in the attendance of young persons at evening schools during the session just ended over that of the previous session. With such hopeful encouragement from the attendance of last year, it is expected that the attendance for 1917–18 will be greater still than that for 1916–17.

Under the Glasgow scheme boys at the day school are not encouraged to specialise in trade subjects, and trade classes, as such, are not provided. In all local centres of industry evening continuation classes and technical classes are organised—the former acting as a connecting-link between the day schools and the technical classes and the latter providing a course of instruction which prepares the student for the higher technical instruction at the Royal Technical College, Glasgow. The local technical schools are affiliated to the Royal Technical College, and the course of instruction is thus maintained at a uniform standard. The development of the purely trade classes has not been rapid, and has been very seriously hindered by the war. This is quite in accordance with expectations, as late work has rendered it quite impossible for students to continue attendance at such classes.

The main points of difference between the two schemes are that whereas London provides for and encourages specialisation at an early age, Glasgow does neither. Nor is there in the Glasgow district any case of the School Board providing tuition for classes held inside or in connection with one works or group of works exclusively—although there are several cases where firms provide tuition for their own employees within their works. In favour of early specialisation and its natural corollary, special instruction, it can be urged that as so many lads receive little or no education after leaving school, it is better to concentrate upon the subjects which contribute directly to success in future business life, while, on the other hand, it may be said that the time available for general education is already too short for the end in view, and cannot without serious loss be curtailed, and the specialised trade or business education must therefore come later. It is now generally conceded that the basis of education must be broadened if real benefit is to be derived from it, and it does not seem possible to accomplish this satisfactorily in conjunction with a specialisation which could be of any benefit.

The spirit in which the solution of the important educational problem has been tackled and the results achieved to date by the responsible authorities of London and Glasgow are alike encouraging, and justify the hope that the return to normal conditions after the war will see a very important extension of the facilities now described. As has already been said, the importance of the service which employers of labour and heads of commercial concerns can render to the success of education, both in the day schools and in the evening technical and trade schools, cannot be overestimated. It is only when the want to be supplied is definitely known that an intelligent effort can be made to supply it, and it lies within the power of the leaders of industry to formulate their requirements of employees, and then to confer with educationalists as to the best means of achieving the desired end. In this way only can rapid and efficient progress be made with the reorganisation of educational aims and methods to meet the changed conditions of life under modern conditions. Fortunately there is the evidence of both the London and Glasgow authorities for the belief that employers are now not only co-operating freely in the fixing of courses of study, but are affording additional facilities for the attendance of their employees at these courses.

NOTES.

THE ECONOMICAL USE OF SHIP TONNAGE.

THERE is no need to enforce the vital necessity of economically using all ship tonnage, or, rather, the carrying capacity of all available tonnage. The absorption of so many mercantile ships for war service and the depletion of our fleet by war wastage make the necessity obvious, even to the layman. We therefore commend to the Shipping Controller and all in authority a promising and practical suggestion made by Mr. William H. Taylor, in an article in this week's *Textile Recorder* (Manchester). The effective use of the holds of a ship depends upon the density of the goods carried being such as will closely approximate to the deadweight capacity. Where the density is low, as with cotton, timber, &c., the holds may be filled without the ship being laden to her designed loaded draught. Mr. Thomson's contention is that cotton could be compressed to a much higher density than is now the case. He shows that the average density of the American bale is only 22 lb. per cubic foot, the Egyptian bale 37 lb., and the Indian and Chinese bale about 56 lb. Thus a ship of 5,000 tons deadweight capacity, and assuming 40 cub. ft. per ton, will only take 1,960 tons of American cotton, as against 3,333 tons of Egyptian, and 5,000 tons of Indian and Chinese. In other words, if 6,000,000 tons of cotton have to be transported across the ocean, the American system of baling cotton would absorb 3,061 vessels of 5,000 tons deadweight capacity, the Egyptian 1,800 vessels, and the Indian and Chinese 1,200 vessels. Alternatively, if the transport were extended over a year, each ship making 12 voyages, the number of ships required would be respectively 255, 150 and 100. Thus Lancashire mills could be kept going with 155 fewer ships were the American cotton compressed to the same high density as the Chinese and Egyptian. Apart altogether from the greatly reduced capital cost of ships, which would be a permanent saving, the gain in carrying capacity during the war would be of immense advantage. What is needed is to overcome conservatism on the part of American cotton compressors, because there is no difficulty from the textile or mechanical standpoint. The cost of the new compressors—3,000*l.* each—would be small when compared with the capital saving on ships. There would be a great economy in transit by rail and road. Mr. Taylor says that the press companies of the United States ought to be patriotic enough to see the necessity of adopting high-density methods of compressing cotton, especially on account of the war, quite apart from the use of the method after the war. They cannot, however, be expected, even for the sake of future gain, to launch out into this tremendous expense of equipment as a mere emergency measure. For it must be remembered that the United States, Great Britain, France, Russia and Italy, and particularly the two first named, would be benefited as a whole, quite as much as the planters and shippers themselves. "As an emergency measure, therefore, it is up to the Governments of Great Britain and the United States, in the joint interests of themselves and the whole of our Allies, to formulate a scheme in co-operation with the Southern planters and compress companies, and with the spinners and manufacturers of Lancashire, to enable new high-density equipments to be installed as rapidly as possible." In Great Britain the movement might very well be initiated under

the auspices of the Board of Trade, headed by Sir Albert Stanley, in co-operation with the Cotton Control Board.

THE LIMITING DIMENSIONS OF FLYING MACHINES.

The fact that the weight of the largest flying bird is relatively low constitutes at least an *a priori* reason for believing that no very extraordinary increase in the present dimensions of flying machines is to be expected in the near future. Mechanical flight became practicable only when the weight of prime movers per horse-power developed had been reduced, as the result of motor-car development and experience, to an unprecedently low value. No doubt the petrol engine is still capable of improvement, but a complete revolution in the character of the power plant would be necessary to any extraordinary increase in the weights now possible. At a recent meeting of the Aeronautical Society Lieutenant A. R. Law gave an interesting curve representing an attempt to fix these limits on the basis of present knowledge. The curve, it is interesting to note, is based on data collected before the war, and in spite of the rapid march of improvement during the past eventful three years, it is still in good accord with the facts. Though no machine yet built has given a better performance than the ideal machine to which the curve relates, there are, however, now some indications that the improvements in materials and design may, in the near future, render possible some slight advance on the limits indicated. In determining the curve, an ideal machine was assumed embodying in every element the best coefficient of performance ever attained with any one of these elements. It was supposed to have the lowest weight per horse-power of engines and accessories recorded up to date, the lowest coefficient of glider weight, the highest engine and wing efficiency, and the highest propeller efficiency. The figures for these were largely taken from the reports of the army trials held some eighteen months before the outbreak of the war, and it is not a little notable that no machine yet constructed has shown a performance superior to that indicated on the curve. Of course glider weights may be reduced by adopting low factors of safety, and in military machines it is, on the whole, economical to run some risk in this respect. Moreover, if the "useful load" is reduced, naturally an apparently better performance will be realised, but the endurance will be correspondingly lowered. The curve has been drawn on the assumption that the useful load, which comprises petrol, passengers and stores, is one-fifth of the total weight carried. The ordinates represent the "ceiling" heights attainable with given total weights. Thus at sea-level flight is possible with a total weight of 12½ tons, of which 2½ tons may be useful load. If, however, the machine is to be capable of attaining a height of 10,000 ft., its total weight cannot exceed 5 tons, unless the useful load is reduced—which is taken, it will be seen, at 1 ton. With empty tanks of course the machine could rise above the 10,000-ft. level. It will be noticed that if a level of 25,000 ft. is to be attained the limit of total weight is brought down to 1 ton if the useful load is 2 cwt. The reduction in carrying power with increase in height is due to the corresponding reduction in the density of the air. The limit of weight varies nearly as the cube of this density, and the heights attainable have accordingly been plotted as ordinates against the ratio $\frac{\rho^3}{\rho_0^3}$ as abscissæ, ρ_0 being the density of the air at sea-level and ρ the density at any other level.

STRESSES IN ROTATING DISCS: ERRATA.—The following misprints require correction in the article on the above subject published in our issue of August 3 last. Page 109, column 3, line 23, for "σ_2" read "σ_r." Same page and column, line 29, for

$$\text{"}\sigma^1{}_r = \sigma_3 \frac{m_0\,\psi_1 - \psi_2 - m\,\psi_1 - \psi_2}{m\,1 - \psi_2\,(m_0\,\psi_1 - \psi_2)}\text{"}$$ read

$$\text{"}\sigma^1{}_r = \sigma_3 \frac{m_0\,\psi_1 - \psi_2 - m\,\psi_1 - \psi_2}{m\,1 - \psi_2\,(m_0\,\psi_1 - \psi_2 - 1)}\text{."}$$

Page 112, middle column, line 2 from bottom, for "$x^2\,\psi_1$" read "$x_2\,\psi_1$."

THE INSTITUTE OF METALS.

The autumn meeting of the Institute of Metals was held at the rooms of the Chemical Society, Burlington House, on Wednesday last, the President, Sir G. T. Beilby, occupying the chair.

THE NEW COUNCIL.

The secretary read the list of officers for the ensuing year, as nominated by the council, which was as follow:—President, Professor H. C. H. Carpenter; vice-presidents, G. A. Boeddicker, Sir Thomas Rose and Walter Rosenhain; members of council, L. Archbutt, Professor C. A. Edwards, Rear-Admiral George Goodwin, C.B., Sir Robert Hadfield, G. Hughes, R. S. Hutton and Sir W. E. Smith. The secretary further added that there had been a large accession of membership since the last meeting, over 100 new names being submitted.

FATIGUE FAILURES OF BRASS.

A paper entitled "Experiments on the Fatigue of Brasses," contributed by Dr. R. Parker Haigh, was then taken. We reproduce this in full on page 315.

The discussion was opened by Mr. Arnold Philip, who suggested that it would be of interest to have for comparison the results of tests in which the variation of stress with the time did not follow the simple sine law, as it did with the apparatus used by the author. The fact established in the paper that the endurance of metals to fatigue stresses might be greatly reduced in the presence of corrosive agents was highly important. An influence of this kind had, however, been more or less suspected for some years past. In fact there was a rough idea that boiler plates subject to periodic variations of stress due to alternate expansion and contraction by heat corroded more readily than unstrained metal. One explanation of this which had been put forward was that the products of corrosion were displaced by the motion of the plating, thus opening up fresh surfaces to attack.

Dr. Cecil Desch, who followed, said that he had seen the author's apparatus, and considered the method adopted particularly good, and he said this after experience with other apparatus. There was a substantial advantage in having the definite sine law of loading, as tests were then strictly comparable *inter se* and were accurately reproducible, which was not the case when the variation of stress with time followed, as it usually did, some indeterminate law. There were two possible explanations of the effect of corrosive agents on the endurance of the specimens. This might be due, as Mr. Philip had suggested, to purely mechanical displacements opening up the structure of the metal, allowing the reagent to be drawn in and giving rise to inter-crystalline separation of adjacent layers. Secondly, if the amorphous phase were produced as a consequence of the stress, this would be more readily attacked than the normal metal.

Dr. Walter Rosenhain, who spoke next, said the paper filled a gap in technical literature which had been very palpable to those at work on the subject of fatigue. It had in fact been necessary, in discussing the fatigue of non-ferrous metals, to base conclusions on experience with steel owing to the lack of data for the brasses. The experiments in the paper had now definitely shown that the two classes of metals behaved under fatigue tests in much the same way. A point of interest was the failure to establish any close connection between the primitive elastic range of the metals tested and their endurance under alternating stress. This matter would require further careful study. Whether there was this physical difference between brass and steel was a matter of first-rate importance. The effect of corrosion on endurance was partially raised in the paper, and had occupied the attention of all who had investigated actual fractures. The failure of steam boiler plates under the conditions named by Mr. Philip were well known. though the speaker did not accept the explanation put forward. In service a groove often formed along the line indicated in Fig. 1, and was due merely to corrosion. In exceptional cases a crack started in the bottom of this groove and went through the plate, which failed thus along a line where there was more metal to break through than there was along the line of the rivet holes. The ultimate cause was not the mechanical displacement of the products of the corrosion, but the fact that amorphous metal was produced by the straining, and this had a greater power than the normal phase of absorbing gases. If these were of a corrosive kind the breakdown of the metal was facilitated. This effect had been well illustrated at one of these meetings some years ago, in which a bar of cold rolled brass "burst" when immersed in a solution of mercuric chloride. In this case

Fig. 1.

no doubt the corrosion was of a greatly accelerated type. In Dr. Haigh's experiments the action was less violent but was long-continued. If, as had been suggested, the oxygen of the air might have acted as a corrosive agent during endurance tests, it would be of interest to make tests with the specimens protected by a film of oil, and to ascertain whether, thus treated, they would endure longer than when clean and dry.

Lieutenant Jenkins asked if the author could give any information as to the minimum size of scratch which would be likely to have a deleterious effect on the endurance. Was it necessary to burnish the pieces? Fatigue failures starting in sharp corners and in scratches were, he might say, common in aeroplane engine practice. Again, would paint suffice to protect metal under alternating stress from the action of corroding agencies?

In reply Dr. Haigh said that the advantage of the sine function lay chiefly in the greater ease with which the apparatus was calibrated. He believed that with the stress varying according to another law somewhat different results might be recorded, but he had not investigated this and hardly felt inclined to do so. By reversing one of the magnets of his apparatus, which was, it should be noted, fed with two-phase current, the two magnets might be made to give a steady pull, which could be easily measured by an extensometer. In practice it was not possible to so completely get rid of the higher harmonics as to get the pull absolutely steady, but the result was very approximately achieved; and a very useful check on the calibration of the tester could in this way be obtained. Dr. Desch and Dr. Rosenhain had raised the question as to the effect of corrosive gases, and the possible protective action of oil or paint. He had not tried this, but he had noted that the oil in the screw couplings of the tension bars of his machine carbonised very rapidly when the machine was at work. It was difficult to fix a safe limit to the depth of scratches. What he had done was to use a very fine wheel in grinding up his test pieces, but he had not burnished them, as he feared that the surfaces stresses thus produced might have a worse effect than the fine scratches left by the wheel he used. As to fillets, a very small one was better than none.

Fig. 2.

In making large fillets, however, there was a danger that the workman might produce something like the profile represented in Fig. 2, which showed a dangerous shoulder.

Sir George Beilby asked the author if he had tried low temperature annealing, as he had found some years ago that a temperature of even 100 deg.C. might afford a very great relief of strains, getting rid of all those which would naturally disappear with time, though it produced no re-crystallisation of the metal.

In reply Dr. Haigh said that he had found that a bar of steel strained some 5 per cent. to 10 per cent. beyond the yield-point, and then subjected to a fatigue test, gave better results if annealed at the low temperature stated, although the ordinary tensile test was unaffected.

Sir George Beilby added that he thought the usefulness of hard-drawn wires would be increased by steam annealing.

HARDNESS OF METALS.

A paper by Professor T. Turner, on "Hardness and Hardening." was next taken. In this the author criticised Le Chatelier's suggestion that it was impossible to measure hardness, since the quality in question followed neither the law of equivalence nor that of accumulation. In Professor Turner's view this was to unduly restrict the use of the word "measure." The author defined hardness as the property whereby one body was able to penetrate another; and said that this was really equivalent to Osmond's definition of hardness as "resistance to permanent deformation," and to Hadfield's definition as "resistance to deformation." He criticised the Brinell test because an appreciable quantity of metal was displaced by it, this displaced material becoming, in consequence, more or less work-hardened. He did not consider resistance to wear and hardness as interchangeable. All hardening was due either to alloying or to cold working. Hardness produced by cold working was, he suggested, due to the amorphous films (separating the softer crystals) being in a state of tension. The interior of the crystals was thus in a state of compression. On this view it was easy to see why it was impossible to harden the whole of the material of a bar by cold working it, since enough of the normal material must remain to take the pull of the tensions in the amorphous films. We shall publish this paper in full in another issue.

The discussion was opened by Colonel Belaiew of the Russian Artillery, who observed that the Brinell test had added much to our knowledge of materials in spite of the fact that in making it there was, as the author said, an appreciable displacement of the metal, which could accordingly not be tested a second time in the same spot. In practice this mattered nothing, as a fresh spot was chosen for the second test. There was, however, one important point to be attended to in making Brinell tests, and that was to make sure that the conditions were strictly comparable. All alloys had a network structure, and different results would be obtained accordingly as the ball lay entirely within a single cell of this network or bore upon more than one mesh. If these meshes were very large, as they might be in some cases with steel, the test would give the hardness of the pearlite, whilst if the ball bore on two cells, an entirely different figure would be recorded. This, however, would not indicate that the test was inaccurate, or that the metal lacked homogeneity, but merely that too small a ball had been used in making the test. In short, in making Brinell tests it was important, if we wished to get the full benefits of the system, to pay attention to both the micro- and the macro-structure of the alloy under examination. Discordant results were, therefore, often due to the fact that different components of the alloy were being tested in different cases.

Mr. Cosmo John, who spoke next, said that the word hardness had already been appropriated and defined by mineralogists, and this definition was well understood, although not of a quantitative character. Much conflict and difficulty had arisen from using the term for properties of entirely different kinds He could not agree with the author's suggestion that hardness should be defined as resistance to interpenetration of one body by another. Under certain conditions soft bodies could readily penetrate much harder ones. What the Brinell test measured was the yield-point or tenacity, and there was no necessity to introduce the term hardness, which was really measured by the resistance to abrasion. The difficulty was to get a sufficiently hard standard of comparison. In the speaker's view no method of testing hardness was applicable to a conglomerate. In the case of iron and steel an amorphous phase was produced by cold working, and material thus treated had a very low elongation. It was necessary with such materials to state the condition to which the hardness was referred. In this connection he thought it would be well to drop the term amorphous phase and treat the altered material as an undercooled liquid having a high viscosity comparable to that of a solid, and which could accordingly be tested for hardness by abrasion. He did not think that much progress would be made till the use of the term was restricted as he suggested, instead of being applied indiscriminately to a variety of properties.

Dr. Rosenhain said that the author had opened up a very wide subject, and he did not think the matter of defining the term hardness could be settled in quite the breezy fashion adopted by the last speaker, who took them to task for applying the term to a mixture of physical properties. As for the proposal to consider hardness as resistance to abrasion, this resistance was not a simple property. In the first place the abraded metal had to resist penetration by the testing point, and in this resistance tenacity and other qualities were involved. Hence such a definition was no simpler than any other. As a matter of fact, the principal concern in practice was the hardness of conglomerates, and it was necessary to have a definition of what was to be understood by the hardness of an alloy. The speaker would suggest that hardness was the property, not of a material, but of a surface, and the hardness of a surface was measured by the stress it could withstand without permanent deformation. His suggestion was to idealise the Brinell test, and to define hardness as measured by the load which would, in a Brinell test, give an infinitely small permanent indentation. The objection to the ordinary Brinell test lay in its changing the structure of the metal. If it were possible to eliminate this, and determine the pressure which would just not produce a permanent mark, the value of the test would be increased. This would be difficult in practice, and we should probably have to be content to measure the first perceptible indication of deformation, just as in tensile tests the yield-point was defined by the stress at which permanent elongation first became capable of detection. As now applied, we had in the Brinell test a constant load and a variable indentation. It would be better to have a variable load and a definite deformation. He thought that there was a good deal to be said for the author's theory of work-hardening, but he could not follow him in all the details, though he did in the suggestion that the amorphous films were in a state of tension and the rest of the metal in compression. This, however, was not new, having been put forward by Humphrey some years ago to explain why raising the elastic limit in tension lowered that in compression. Obviously, if the first deformation left in the interior of the specimen films strained in tension, less external load should be required to produce yield on compressing the strained material. The theory was very pretty, and worked in very well, but it was difficult to find a direct proof that the condition in question actually existed. If two Johanssen gauges were pressed together, they would adhere, and require a considerable effort to separate by a direct pull; yet the adherent surfaces would slide over each other with comparative ease. Similarly, with crystalline forms, although the atomic attractions might be large, deformation by sliding was relatively easy. When, however, owing to cold working, the space lattices were deformed, the resistances to be overcome might include direct forces between adjoining surfaces, and not merely a sort of frictional resistance to sliding. The metal, accordingly, would be harder. In this way a picture might be formed of what happened when a crystalline structure was interrupted by the effects of plastic strain.

Dr. Hatfield said that it seemed a waste of energy to try and define hardness. It would be better, rather, to analyse the different properties concerned. The Brinell test was not a valuable guide to the machining properties of a material, nor was hardness a definite indication of resistance to wear, which was practically the same thing as resistance to abrasion, to which Mr. Cosmo John wished to restrict the term. Dr. Rosenhain's suggestion was of interest, but it might fail owing to the fact that a less stress as ordinarily measured would produce greater permanent sets with increasing thicknesses of the specimens. Professor Turner's definition appeared inadequate as it stood; to be satisfactory the resistance to interpenetration must be that shown in static tests. The author had said that the Brinell test measured the pressure a surface would stand without deformation. With a 90-ton steel the figures obtained, using the Brineli test were: diameter of deformation, 3.05 mm., Brinell number = 4.05, corresponding stress, 255 tons per square inch. The stress in the hardness test was thus much higher than in the tensile test. In this connection it should be observed that brittleness was not the direct opposite of ductility, as some steels which were very ductile as reckoned by their elongation under tensile test proved very brittle in shock tests. It would be interesting to know if this was also the case with non-ferrous metals, and if these also might be ductile in tensile tests and fragile in impact tests.

Mr. Ellis said that Dr. Rosenhain had referred to the Brinell test as a means of estimating the yield-point, and it was of interest to note that Brinell had used his method for this very purpose by determining the least pressure which would produce a visible deformation of the polished surface of a specimen undergoing a tensile test. Professor Turner had attributed to Heyn the method of investigating the internal stresses in a work-hardened bar by turning off successive layers, but this method had been followed at Watertown as far back as the nineties. A simple method of determining the existence of such strains in bars of non-ferrous metal was to slot them longitudinally. The speaker had done this to convince a manufacturer that certain failures were due to the existence of such stresses, and not, as the maker contended, to a cold wind blowing on one side of the bar and not on the other. He thought that it might be possible to have the connection between hardness and the surface molecular energy of a material expressed in terms of $S\left(\frac{A^{\frac{2}{3}}}{\rho}\right)$, where S denoted the surface tension of the metal and A its atomic volume. With cold-worked materials the product of the tenacity into the elongation was generally diminished, a fact which went far, he thought, to prove the truth of the amorphous film theory.

Dr. Desch said that greater precision would be necessary if a satisfactory definition of hardness was to be obtained. If hardness was resistance to penetration, then the word penetration itself required definition. The penetration in the Brinell test was quite different from that due to cutting tools. His own experience was that the mineralogists' test of hardness was of greater value in fixing "machining" hardness than was the Brinell test. The original mineralogists' sclerometer was capable of great accuracy and could be improved upon. Mineralogists used a Jaggers diamond drill, which was rotated against the specimen, supported on the stage of a microscope, through which the operation was watched until a certain definite penetration was attained. By this process the hardness of the different constituents of an alloy could be determined separately, by using a small enough diamond. The instrument, however, was not suited to the workshop. The method attributed to Heyn of determining internal stresses by machining off successive layers of cold-wrought material was even older than Mr. Ellis had suggested. It was fully described (in English) by a Russian experimenter some forty years ago.

In reply Professor Turner said that Colonel Belaiew was undoubtedly right in pointing out that even in the same specimen two different materials might be tested by the Brinell method. As to the necessity of excluding dynamic tests in defining hardness as resistance to penetration, the speaker had already noted this in a paper published by the Iron and Steel Institute. He thought that hardness determined as Dr. Rosenhain had suggested would be much the same as if measured by the production of a scratch of standard width. The mark from a point would be difficult to see, a line being better in this regard, but otherwise there was little difference between them. As to Dr. Hatfield's remarks, he would ask how it was possible to have analysis without definitions as a necessary preliminary. It was quite true that a material ductile in one test might be brittle in another, but this did not imply that brittleness and ductility

were not opposite properties, the material being actually ductile in the one case, and brittle under other conditions. The term hardness was in use long before mineralogy was invented, and he disputed the attempt to restrict it to the mineralogists' definition. Resistance to abrasion would not serve as a definition, since copper was more difficult to grind than hard steel, filling up the pores of the emery wheel. He came back, therefore, to the view that hardness was the resistance of a surface to deformation.

Annealing Cold-Rolled Aluminium.

Professor H. C. H. Carpenter then gave an abstract of a paper on "The Effects of Heat at Various Temperatures on the rate of Softening of Cold-rolled Aluminium." This paper described experiments by himself and Mr. L. Taverner, demonstrator of metallurgy at the Royal School of Mines. The points established were that work-hardened aluminium softened rapidly on exposure to a temperature of 300 deg. to 550 deg. C., its tensile strength falling from about 11 tons to 5¾ tons. Annealed at 250 deg. C. the effect was slower, but the final result was the same, and was attained in from 600 to 800 hours. It was further found that annealing proceeded even at as low a temperature as 100 deg. C., but after a somewhat rapid initial drop of strength the tenacity again rose with a longer exposure, to sink again, later on, to a value which, in the course of perhaps three years, would be apparently the same as the final result at higher temperatures. We intend to reprint Professor Carpenter's paper in full in a future issue.

In declaring the discussion open Sir George Beilby asked if the specimens were all ¼ in. thick, and, on receiving an affirmative reply, said that he had found that the actual mass of the metal had a considerable effect on the time taken to complete changes. With extremely fine wires, for example, quite different results were recorded than with stouter ones.

Dr. Seligman said that there was both a scientific and a practical aspect to the experiments described in the paper. In the first place he might note the very close parallelism between the results of the mechanical tests and those of the speaker and Mr. Wilson on the chemical properties of the material. He thought the tests showed that the annealing process was not as simple a matter as it was sometimes said to be. In the low-temperature tests there were apparently two—at least two—distinct phenomena concerned, which was in accord with Howe's view as opposed to that of Le Chatelier. The author's specimens contained silicon, and there was evidence to show that in cold-worked aluminium 57 per cent. of the silicon was present as silicon, whilst it was all combined in the soft metal, though he understood that Rosenhain held that it was really the origin of the metal which fixed whether the silicon was combined or graphitic. If cold rolling did have this effect it was a very peculiar phenomenon. He asked if the degree of cold working affected the temperature at which annealing would commence. Hitherto for information as to the behaviour of aluminium at different temperatures they had been dependent on three papers—one by Bengough, another by Le Chatelier, and a third by Baumann. All had the defect of not taking into account the permanent effects of the temperature on the metal. The present paper therefore filled a gap. Thus Bengough found that a specimen with a normal tensile strength of 8.6 tons retained when heated to 275 deg. C. 57 per cent. of its strength. It was now known that, given sufficient time, this figure would fall to 50 per cent., even if the test were made after cooling to 20 deg. C. Hence the test at 275 deg. gave merely the momentary value of the resistance. He had but two criticisms to make. The author declared that work-hardened aluminium was useless if liable to exposure to 200 deg. C. He thought this was going too far, as there were cases in which it might be necessary to use it at this temperature, but it was, of course, then impossible to rely upon the strength due to the work-hardness. He also thought that the anticipation that at three years the strength would be lost even at temperatures in the neighbourhood of 100 deg. C. was possibly too unfavourable. Quite a small change in the assumed shape of the extrapolation curve would give a life of nine years.

Dr. Gwyer, who spoke next, said the results recorded in the paper agreed with his own experience, though he had made no experiments at very low temperatures, nor had he gone in for very long period tests. He could, however, confirm the conclusion that in all cases the final result was the same. He noted that the metal used contained some 0.35 per cent. of Si. This was rather high for the commercially pure metal, and the iron at 0.72 per cent. was extraordinarily high. The author stated that the metal had been severely cold worked. It would seem, however, from the tensile strength given of 11 tons per square inch, that this was not in any way abnormal. Metal of the gauge stated generally ran to about the figure quoted. Thus, in his own work, specimens with 0.45 per cent. of silicon and 0.55 per cent. of iron, rolled by the ordinary methods, had a tensile strength of 10.45 tons when the thickness was ⅛ in. The corresponding elongation was 8.5 per cent. He considered the figure given for the primary elastic limit of the metal as of extraordinary interest. The speaker had found that aluminium resembled gold in having no definite annealing temperature, and for practical purposes he had assumed that softening had commenced when the tensile strength dropped ½ ton per square inch, and this fall might occur over a range of from 40 deg. to 200 deg. C. The thickness of the metal was important. Thus, with ¼-in. plate the tensile strength began to drop at a temperature of 240 deg. C., but the final state was not reached in 480 hours. With the metal rolled to ⅛ in., softening began with temperatures between 130 deg. and 220 deg., and the final state was reached in 450 hours to 480 hours. When $\frac{1}{16}$ in. thick, the strength fell ½ ton at 80 deg. C.

In reply Professor Carpenter said that the temperature at which annealing began was affected by the degree of work-hardening—the greater the cold working, the lower the temperature at which annealing began. The effect of the relatively large silicon content of his specimens was that the softening proceeded rather quicker, but the copper and iron had little effect.

Etching by Chromic Acid and Hydrogen Peroxide.

A note by Mr. S. W. Miller, on "The Use of Chromic Acid and Hydrogen Peroxide as an Etching Agent," was taken as read, and the meeting adjourned, to meet again at 8 o'clock, when the following papers were taken: (5) "Further Notes on a High-Temperature Thermostat," by Mr. J. L. Haughton, M.Sc. (Teddington), and Mr. D. Hanson, M.Sc. (Teddington); (6) "Principles and Methods of a New System of Gas-Firing," by Mr. A. C. Ionides (London); (7) "Fuel Economy Possibilities in Brass-Melting Furnaces," by Mr. L. C. Harvey (London); "The Effect of Great Hydrostatic Pressure on the Physical Properties of Metals," by Professor Zay Jeffries, B.Sc. (Cleveland, U.S.A.). We shall deal with the proceedings at the evening session in our next issue.

Oxidising Gases in the Tropical Atmosphere.—Two reasons are suggested for the rapid decay and bleaching which rubber goods and fabrics of silk and cotton undergo in tropical climates: the intense light and heat, and further—since the decay is rapid also in the dark—a higher percentage of such active gases as ozone, hydrogen peroxide and oxides of nitrogen in the tropical atmosphere than in our atmosphere. As there are hardly any data concerning these percentages, Professor F. L. Usher and Mr. B. S. Rao (Transactions of the Chemical Society, August, 1917, pages 799 to 809) resolved to determine them at the Bangalore College, in India. The determination of traces of gases in large volumes of other gases is always very difficult, and in the case of these three gases particularly so. Professor Usher found that alkaline or neutral sodium nitrite is a reliable reagent for the ozone determination. The preliminary account referred to describes the method in detail. Only 14 complete determinations had so far been made, and in 12 of those none of the three gases were found; in the other two cases traces of nitrogen peroxide were discovered. The experimenters do not wish to draw any conclusions; but they point out that apparently nitrogen peroxide and ozone cannot exist together in the atmosphere, as they would react under formation of nitric acid. Perhaps the moist, hot atmosphere, favouring fungus growth and other decay, is mainly responsible for the destruction of the materials mentioned, in accordance with the popular belief.

THE IRON AND STEEL INSTITUTE.

The autumn meeting of the Iron and Steel Institute opened yesterday, and is being continued to-day, in the hall of the Institution of Civil Engineers, under the chairmanship of Sir William Beardmore, Bart.

Sir William announced that the Council had nominated Mr. Eugéne Schneider, the well-known French ironmaster, to be the next president, and that Mr. Schneider had accepted.

The first paper taken at yesterday morning's meeting was the one by Messrs. G. Barrett and T. B. Rogerson, on "Present Practice in Briquetting of Iron Ores." It was read in abstract by the former. We reproduce it in full on page 299.

The next paper on the list was on "New Experiments on Shock Tests and on the Determination of Resilience," by Mr. G. Charpy and Mr. A. Cornu-Thenard; it was read in abstract by the secretary. It was followed by the paper entitled "Notes on the Heat Treatment of Grey Cast-Iron," by Mr. J. E. Hurst, who read it in abstract.

It will be remembered that five technical committees have been formed of members of the Institute. Committee No. 3, for steel and its mechanical treatment, the chairman of which is Mr. George Ritchie, and the vice-chairmen Mr. A. J. Capron and Mr. E. H. Saniter, held its first meeting yesterday afternoon, when the preliminary reports of the metallurgical and of the mechanical sections were read and discussed.

We propose to report the proceedings fully in our next issues.

The New Quebec Bridge.—The erection of the 5,000-ton suspended span of this gigantic structure was commenced on Tuesday last and has proceeded satisfactorily up till the moment of going to press. The plan of erection followed is in essentials the same as last year, when, it will be remembered, the failure of a casting used for part of the hoisting tackle led to the overturning of the span and its fall to the bottom of the river.

Reconstruction of the Niagara Cantilever Bridge.—The cantilever bridge at Niagara Falls, built in 1883–84, to the designs of the late C. C. Schneider, is to be replaced by a steel arch. This bridge had to be strengthened in 1900 to meet the large increase in the weight of trains which had occurred since the design was prepared. This rise in the intensity of the rolling-load has now progressed further, and, to meet it, it has been decided to rebuild the bridge as a steel arch, with a span of 560 ft.

Machine Tools.—The use of milling machines and grinding machines, says *Machinery*, New York, has increased greatly during the past ten years, and these machines are now regarded generally as standard machine-tool equipment. There is little question of the superiority of the milling machine over the planer or shaper for manufacturing parts in large quantities. Nor can the place of the grinding machine as a follower of the lathe for finishing cylindrical surfaces be longer denied. But notwithstanding the great increase in the use of these machine tools, the lathe is still the recognised leader of all. More lathes are built and sold than any other machine tool, except drilling machines. Planers have their place in the machine shop, and will always be used for jobbing and repair work, and probably for planing the working surfaces of machines that must be highly accurate. The shaper and slotter have their recognised places also. The point to be made is that the development of any type of machine tool does not necessarily, if ever, result in displacing another; it may, in fact, make a better and broader market for all.

Ministry of Labour Employment Department.—The Ministry of Labour has issued a memorandum with regard to the constitution and functions of the Local Advisory Committees now being formed in connection with the Employment Exchanges. Reference to these committees was made in a resolution passed by the Trade Union Congress at Blackpool this month, to the effect that "It welcomes the appointment of Advisory Committees to assist in the work of Employment Exchanges, provided they are collectively nominated by the bodies to be represented, and the duties assigned to these committees should be extended so as to give them a real opportunity for rendering service to the department." Among the most important functions which it is hoped the committees will perform immediately is that of facilitating the work of providing substitutes for men released for the Army, and generally assisting to promote the most advantageous use of the available man-power of the country. The Minister of Labour is extremely gratified at the response made by associations of employers and workpeople to his invitations to nominate members for these committees. Good progress is being made in the formation of the committees, and the representation of employers and workpeople on about a hundred committees is now almost complete.

INDUSTRIAL NOTES.

THE Director of the Department of Labour Statistics, writing on the state of the labour market in *The Labour Gazette*, states that in August nearly all the principal industries were fully employed, and in many cases much overtime was worked. In the woollen and worsted trades, however, reduced hours were again the vogue in accordance with the Wool (Restriction of Consumption) Order, 1917, and the effect of this restriction was also felt in several of the other textile trades.

The average weekly number of vacancies notified to all Employment Exchanges for the four weeks ended August 10, 1917, was 32,626, as compared with 36,904 in the previous five weeks, and with 39,113 in the four weeks ended August 11, 1916. The average weekly number of vacancies filled for the same periods was 24,915, 28,222 and 30,846 respectively.

The changes in rates of wages (including war bonuses) reported to the department as taking effect in August affected nearly 1,400,000 workpeople, and resulted in a net increase of nearly 180,000*l.* per week. With few and comparatively unimportant exceptions, the changes were all increases.

The number of disputes beginning in August was 49, and the total number of workpeople involved in all disputes in progress was 63,735, as compared with 45,425 in the previous month and 21,096 in August, 1916. The estimated total aggregate duration of all disputes during the month was 332,700 days, as compared with 260,600 days in July, 1917, and 78,900 days in August, 1916.

Retail prices of the principal articles of food on September 1 averaged about 2 per cent. higher than on August 1. As the figures relate to September 1, they are prior to the entry into force of the Food Controller's recent orders reducing prices. As compared with September 1, 1916, an average increase of about 25 per cent. is recorded. As compared with July, 1914, the increase is 106 per cent., which, however, falls to 67 per cent. when the possible economies and substitutions are taken into consideration.

The Supreme Court of Washington, says *The Iron Trade Review*, Cleveland, Ohio, has settled a question that has annoyed the State Courts for years, and caused no end of trouble to business houses and industrial plants. It has decided against the peaceful picketing of premises during a strike, declaring it contrary to the spirit of American institutions. The court holds picketing to be intimidation and a form of blacklisting that has been forbidden by the same court in other cases. The court said that "the right to conduct a lawful business in a lawful way, without molestation of other persons, needs no argument to sustain it." In the case under consideration the appellant was able to show a loss of 75 per cent. of his business by reason of the picketing of his premises. The Seattle Labour Council, which carried the case to the Supreme Court, will ask a rehearing. Failing in this, it proposes to take it to the Supreme Court of the United States, on the claim that the Clayton Act legalises picketing and other peaceful activities of organised labour.

Sir Arthur Whitelegge, K.C.B., who has held the appointment of H.M. Chief Inspector of Factories and Workshops at the Home Office for more than twenty-one years, will retire in the course of next month, on reaching the age limit of 65, and the Home Secretary has appointed Mr. H. M. Robinson, the senior Deputy Chief Inspector, to succeed him. An arrangement has been made under which Sir Arthur Whitelegge will continue to give his services to the Factory Department in an advisory capacity on questions of a technical and scientific character. Mr. R. E. Graves, the junior Deputy Chief Inspector, will now become senior Deputy Chief Inspector, and Mr. Gerald Bellhouse, Superintending Inspector of Factories, has been appointed junior Deputy Chief Inspector.

The offices of the Conciliation and Arbitration Board for Government Employees have been removed to Sanctuary Buildings, Great Smith-street, S.W. 1.

On Thursday, the 13th inst., Sheriff Fyfe decided, in the Glasgow Small-Debt Court, a test case in which a workman sued his employers for 2*s.* 4*d.*, alleged to have been illegally deducted from a week's wages, and the employers counter-claimed for 3*s.*, alleged to represent time returned on a time card, which time had not been worked. The men, from Glasgow, were working on a boat at Greenock which was due for delivery, and in order to finish some urgent work it was arranged to work overtime till 9.30 on the day in question. But the last train from Greenock was at 8 o'clock, and to get a full overtime day the squad foreman and the men, unknown to their employers, arranged amongst themselves that they would work in meal hours for 1½ hours and leave in the evening 1½ hours earlier than the usual overtime period, and return their time-cards up to the full usual overtime limit. When they discovered that this had been done, the employers deducted 1½ hours off the pay slip, and this was the 2*s.* 4*d.* sued for. The employers' counter-claim arose on the same practice, but applied to day time, not overtime. The working day ends at 5.30, but on a similar arrangement with their foreman the men had left by a four o'clock train, compensating that, as they said, by working 1½ hours at meal times.

The Sheriff refused the workman's claim and granted the employers' claim, with expenses. The Sheriff said the money value of the case was of small consequence, but the principle involved was important, and reached far beyond the Clyde district. The question of law was whether it was within the scope of a man in the position of this foreman to bind his employer to a serious alteration of the contract of service. He most certainly thought it was not, and the alteration the foreman and the men took it upon themselves to make was a most essential one. The breakfast break was three-quarters and the dinner an hour. He could hardly conceive that the squad could breakfast and dine in 7½ minutes for each meal, and that was all that was left to them if they really put in 1½ hours' work. If they did that it was very bad for them, and certainly would not improve the afternoon's work. But even if it was done they had no right to do it. He could not countenance this sort of manipulation of the overtime hours.

He thought that if it had been the converse case—that the employers were asking the men to work in their meal hours—there would have been a trade-union storm. It was not in the interest of either employers or men that the breaks, which were meant for relaxation from work, should be converted into working hours. The men had not been working during meal hours in implement of any contract of service or in accordance with any usage of trade, and they could not ask to be paid for these hours as working hours. The Sheriff expressed strong disapproval of the whole arrangement, the purpose of which was to enable the men to get paid up to the full time, and for overtime, during the stopping hour, when in point of fact they had not worked up to it.

Mr. L. A. Paish, representing the Department of Commercial Intelligence, Board of Trade, and Mr. C. Hamilton Wickes, British Trade Commissioner in Canada, addressed last Monday, in Birmingham, a large meeting of members of the Brass Masters' Association.

In the course of his address Mr. Paish said that the idea of the new department of the Board of Trade was to get under one control the duty of giving information to the commercial community in this country, and he was sure that the announcement that Sir A. Steel-Maitland was to be the head of it would be greatly appreciated by Birmingham manufacturers. After explaining the cartel system in Germany, the speaker said the Government of that country were making a strenuous attempt to get all their manufacturers into syndicates, and were pressing upon them that the only way in which they could regain their place in the sun was by adopting that form of trading. The considered policy of the Board of Trade, after investigating the question, was that if British manufacturers were going to increase their export trade after the war, if they were going even to regain the trade lost, it was essential to get together in some sort of trade combination. They were prepared to face the question of trusts or combines, because if we were to take our stand it would be absolutely necessary to adopt somewhat similar methods to those abroad. The insane competition between home manufacturers did no good at all. They would get enough competition from abroad without bothering about the man in the next street. The strongest argument in favour of combination in the brass trade was that it would enable manufacturers to specialise in a small range of articles—*i.e.*, they would make a large number of a small variety and not a small number of a large variety. There were many other advantages. One was the possibility that a trade combination covering the whole of the Birmingham brass masters would be able to undertake the systematic investigation of any definite market they wanted to attack. His department was prepared to co-operate, even with financial assistance, in sending out representatives, for it (the department) was out to give manufacturers and traders every possible assistance that they could reasonably expect in the development of the export trade. Another popular advantage of combination was the power it afforded to dump, if required. The department had instructed him to take steps to get a trade association of brass masters actually going. The form of the combination—the cartel or the full merger type—was a matter for themselves.

Mr. Wickes confirmed these statements, and added that at the close of the war the country whose manufacturers were ready and prepared to consider intelligently the problems to be faced and to act skilfully in dealing with them would get a great start over the others.

We are informed that the circular A.A. 50, which was a cause of friction between the Ministry of Munitions and the Amalgamated Society of Engineers, has been withdrawn. The circular in question empowered the recruiting authority to take skilled men from the factories and enlist them for service with artificer units. The Amalgamated Society of Engineers questioned the methods of recruiting artificers. Friendly discussions on the matter are still being followed. At the headquarters of the Amalgamated Society of Engineers it was stated a few days ago that there is no probability of further disputes in regard to wages.

THE BEDPLATES OF TURBINE UNITS.

TO THE EDITOR OF ENGINEERING.

SIR,—In reading a reprint of Mr. Chorlton's paper entitled "Notes on the Construction of Turbine Pumps," read before the Institution of Mechanical Engineers in England—which reprint appears in the May 25 and June 1 issues of ENGINEERING—I was particularly interested in the following section concerning bedplates:—

The bed and other details.—In the past less importance has been placed on the effect of the bedplate than is now the case, with the result that frequently very shallow depths were used. These early beds were much too weak to resist warping strains, due either to the unevenness of the foundation surface, the "pull" of holding-down bolts, or to the reaction of the torque from the motor end. It was a common practice to design bedplates in the form of two separate horns or branches, and in this case deeper sections were generally employed. This form of design, while undoubtedly stronger against bending, depends too much upon the skill of the plant erector and the solidity of the foundation always to give good results. It must be obvious that if fine internal clearances, such as have been dealt with, are an advantage, then the common base for the lot—the bedplate—must be of a nature to ensure the clearance remaining concentric and also to maintain true alignment with the operating motor. For these reasons deeper sections than are usual are an advantage.

Mr. Chorlton's remarks with regard to bedplates are most true, and he might also well have mentioned misalignment due to unusual pipe strains.

As builders of turbine units we are keenly aware of the fact that perhaps 90 per cent. of the troubles on turbine units occur immediately after installation, and are almost invariably due to ignorance of the necessity of the two or more machines of the unit being in the same perfect alignment that they were when erected and tested at the manufacturer's works. In other words, customers are painfully ignorant of the fact that baseplates, no matter how heavy, are usually strained sufficient to cause a misalignment that is serious in high-speed units; and also that the piping to turbine units is usually relatively large compared to the size of the unit, and if not properly designed and erected can often produce strains which will cause appreciable misalignment, particularly if the pipe connections are in the upper part of the machine.

The burden of educating customers to avoid these troubles has up to the present always been on the manufacturer, in addition to its being a source of great expense, as customers usually insist that they are blameless when it comes to paying the bill for realigning of the units and the damage done.

I am sure that all turbine manufacturers would welcome any assistance the technical journals can give them in educating the public to avoid these troubles, which they can readily avoid with a little care, or at least more attention to instruction books than is now given.

Yours very truly,
THE TERRY STEAM TURBINE COMPANY,
N. L. SNOW, Vice-President.
Hartford, Conn., August 30, 1917.

"RECENT DEVELOPMENTS IN AIR PUMP DESIGN."

TO THE EDITOR OF ENGINEERING.

SIR,—I regret that an error has occurred in the text of my paper on "Recent Developments in Air Pump Design," which was read before the Institution of Shipbuilders and Engineers in Scotland in March last, and published in the September 7 and 14 issues of your paper. This error occurs in the description of the Hick-Breguet Ejectair. The quantity of injection water used by the jet condenser, of which other particulars are given, is stated as being 94 gallons per minute. This should read 367 gallons per minute.

I wish to apologise to Messrs. Hick Hargreaves, Limited, Soho Works, Bolton, and also Messrs. La Maison Breguet, Paris, and shall be glad if you will kindly insert this letter in your paper at the earliest possible moment to avoid any of your readers forming an opinion which would be in any way detrimental to either of the above firms.

Yours faithfully,
E. JONES.
The Mirrlees Watson Company, Limited, Scotland-street, Glasgow, September 15, 1917.

THE LATE MR. BENJAMIN WRIGHTSON HEAD.

WE regret to have to announce the death, on the 12th inst., at Westminster, in Orange River Colony, South Africa, where he had gone some time past for the benefit of his health, of Mr. Benjamin Wrightson Head, the fourth and youngest son of the late Mr. Jeremiah Head, and nephew of Sir Thomas Wrightson, Bart. Mr. Head was born at Coatham, Redcar, on May 12, 1875, and received his general education at Repton School from 1889 to 1891. On leaving school he followed a five years' course of practical engineering training, first with Messrs. Head, Wrightson and Co., Limited, from 1891 to 1893, then with Messrs. R. and W. Hawthorn, Leslie and Company, from 1893 to 1896. He then studied at Emmanuel College, Cambridge University, from 1896 to 1899, when he took a double first-class in the Mechanical Science Tripos. On leaving the university Mr. Head entered the staff of Messrs. Jeremiah Head and Son, where he assisted his brother, the late Mr. A. P. Head, and was engaged upon the design and construction of steel-works plant. At this same period he spent six months in studying steel-works practice in the United States. From 1901 to 1905 he was assistant to the late Mr. A. P. Head, becoming his partner in 1904. During this latter period the late Mr. A. P. Head was managing director and consulting engineer to the Otis Steel Company, Cleveland, Ohio, and the subject of our memoir assisted him in this work, both in England and by visiting America. In addition to his connection with the above-named American company, Mr. A. P. Head was the senior and sole European representative of the Wellman, Seaver, Morgan Company, Cleveland, Ohio. Mr. A. P. Head died in June, 1905, and in November of the same year the company Wellman, Seaver, Head, Limited, was formed to take over the European rights of the Wellman, Seaver, Morgan Company, who still retain an interest in the British company. Mr. B. W. Head was managing director and consulting engineer of the British company, and in this capacity he was entirely responsible for all the designing and for carrying out all the work done by it since its inception. This well-known company has made a speciality of the designing and supply of improved steel-works plant complete, among which we may mention Siemens-Martin furnace-charging machines of all types; reheating furnaces for all purposes; fixed, rolling and tilting Siemens-Martin furnaces; metal mixers of all capacities — in short, all apparatus appertaining to the manufacture of open-hearth steel. In the course of his career Mr. B. W. Head took out in his own name, or jointly with others, a number of useful patents. Considerable progress was made by the company prior to the end of 1913, and as the war emphasised the absolute necessity of installing labour-saving appliances in all steel works, the Ministry of Munitions directed that these should be installed wherever possible.

Mr. B. W. Head was an indefatigable worker until his health broke down; he had a successful career, and it is to be regretted that he should have died at the early age of 42, just at a time when his firm is reaping the full reward of patience and persistent effort. He was a M.A. (Cantab.) and a member of the Institution of Civil Engineers and of the Iron and Steel Institute. He was also a member of several clubs, and was very popular among a large circle of friends and acquaintances, by whom his loss will be severely felt. In November, 1907, he married Miss Gladys Hamilton Marriott, daughter of the late Major W. H. Marriott, of the Devon Regiment, and leaves one son.

THE LATE MR. PERCY GRAHAM BUCHANAN WESTMACOTT.

IN our last issue (*vide* page 265 *ante*) we published a memoir of the late Mr. P. G. Westmacott, but we were unable at the time to accompany this notice of Mr. Westmacott's career by a portrait. We have now, however, had placed at our disposal an admirable photograph of Mr. Westmacott, and this we reproduce on the present page, feeling sure that the portrait will be of great interest to the wide circle of engineers to whom Mr. Westmacott was known, and by whom his valuable contributions to the developments of mechanical engineering are appreciated.

[*Lafayette, Photograph.*

THE LATE MR. PERCY GRAHAM BUCHANAN WESTMACOTT.

THE LATE MR. FREDRIK OLE ERICHSEN.

MR. FREDRIK OLE ERICHSEN, whose death, we are sorry to see, is reported by cable from Buenos Aires, was born on August 3, 1869, at Newcastle-on-Tyne, and was the youngest son of the late Mr. Hermann Gustav Erichsen, director of the Great Northern Telegraph Company, and Mrs. Erichsen (*nee* Anna Dorothea Suhr), both of Copenhagen. He was educated at Rugby School, and served a pupilage of three years at the works of Messrs. James Simpson and Co., Limited, Grosvenor-road, London, S.W., from October 1 1887, to October 1, 1890. On completing his pupilage he was appointed to the drawing office staff, and afterwards became chief of the outdoor erection department, in which capacity he superintended the erection of many large pumping engines, both at home and abroad. He was also the leading expert in carrying out duty trials of all the pumping plants installed by the firm, amongst the most notable of which may be mentioned pumping plants for almost all of the London water companies, besides many large plants in the provinces, whilst abroad, included in the many duty trials carried out by him, were those connected with the large pumping scheme for the Coolgardie water supply, consisting of eight pumping stations working under varied conditions as to power. By those trials he established the duty obtained as being in every way up to the specification of the Western Australian Government, which was of the most stringent character, requiring precise and careful tests, and the most close and searching investigation of all the points involved in connection with the trials and their results.

Economic duty trials of pumping plants were also carried out by him at the Kimberley water works, Rand Water Board, and other places in South Africa. It was whilst engaged on similar work that he met his untimely death accidentally, at the age of 48, at Buenos Aires, on the 12th inst. Altogether his professional career with Messrs. James Simpson and Co., Limited, would have extended over exactly 30 years on October 1st next.

Mr. Erichsen was well known as an expert in his special line of engineering, and he possessed in a marked degree the valuable trait of establishing by his sound and effective advice a cordial business relationship with all the clients of the firm with whom he came in contact. Messrs. Simpson, in recognition of his long and valuable services, appointed him, in December, 1914, a director of the company. Mr. Erichsen was highly respected by all who knew him, and will be greatly missed by a large circle of business and private friends. He was elected an associate member of the Institution of Civil Engineers in 1896, and a member of the Institution of Mechanical Engineers in 1901. He was also an associate of the Institution of Water Engineers.

THE UNITED STATES NAVY AIRCRAFT FACTORY.—In announcing the putting down of an aircraft factory at the League Island Navy Yard, Mr. Daniels, Secretary for the Navy, recently stated that, in view of the enormous expansion of the aircraft industry, it was felt necessary to increase the Navy Department's facilities, not only to enable it to supply a part, at least, of its own needs, but also to relieve the private plants of the experimental developments which they have hitherto undertaken, and thus enable them to turn their whole attention to the maximum production of approved types.

EXPERIMENTS ON THE FATIGUE OF BRASSES.*

By B. PARKER HAIGH, D.Sc. (Royal Naval College, Greenwich).

THE term "fatigue" is used to describe the failure of metals in a brittle manner after the continued application of pulsating or alternating stresses. It is the object of this paper to describe certain experiments on the fatigue of brasses, which alloys have hitherto received less attention, in this respect, than mild and alloyed steels. The phenomena of fatigue, for brasses, are generally similar to those for mild steel. It will be shown that the effects of corrosion and fatigue are mutually associated, and that fatigue is accelerated, and occurs under lower stresses, when the conditions tend to promote corrosion.

The experiments may be classified under the following headings:—

1. To ascertain the effects of annealing, using stresses alternating between equal intensities of direct pull and push.

2. To ascertain the relation between the limiting range of stress required to produce fatigue, and the ratio between the maximum and minimum stresses.

3. To study the phenomena of elongation under stresses greater than the fatigue limit, but less than the ultimate tensile strength of the material.

4. To study the influence upon the endurance of the metals under alternating stress of corrosive reagents in contact with the metal.

Method of Testing.—It is not proposed to describe in detail the apparatus used in these experiments, as a short description has already been published.† A brief description will be given in order that the conditions may be compared with those prevailing in practice and in other "live-load" tests. Alternating stresses differ in their nature, which may be of direct pull and push, bending or torsion, and also in the mode of variation, which may be more or less regular, according to the conditions of practice, or the design and construction of the testing machine.

In designing the machines used for these experiments the points to which the author attached chief importance were the following: (1) Variation of stress in direct pull and push, uniformly distributed over the cross-section of the specimen; (2) regular (simple harmonic) time-rate of variation; (3) accurate measurement of the maximum and minimum stresses; (4) adjustable ratio between the maximum and minimum intensities. The following points were also held to be of practical importance: (5) Rapid and adjustable frequency of alternation; (6) permanence of the calibration constants; (7) elimination of lubricated slides, external vibration, and noise; (8) the use of specimens of simple but scientific form.

Fig. 1 illustrates the principle of a small machine intended for testing wires under pulsating pulls up to a maximum of 100 lb., and Fig. 2 a larger machine for a maximum pull or push of 1¼ ton, with a range of variation of 1½ ton. The test-piece, S, is rigidly held at its upper end, which can be adjusted for height to allow for elongation. The lower end is connected to the armature, A, of a single or two-phase electro-magnet, M or M1–M2, excited by alternating current from a generator giving a sine-wave E.M.F. It is characteristic of such a magnet that the pull produced, which pulsates with double the frequency of the electric current, is closely proportional to the square of (voltage ÷ frequency), and nearly independent of the width of the air-gap, so long as this is small. In order to avoid complications, the voltage measured (and used as the basis of calculation of stress) is that induced in a small "secondary" coil containing only a few turns of fine wire wound on a frame close to the pole-faces. In the two-phase machine the pulls of the two magnets, M1 and M2, are equal when the magnetising coils are supplied with equal E.M.Fs., provided that the magnetic leakages from the two are alike. The latter condition is fulfilled when the air gaps are equal, and is attained by raising or lowering the upper end of the test-piece, and thereby the armature, until the currents in the two coils are equal. The range of variation of load is then double the pull of either magnet acting alone, for as the two-phase E.M.Fs. are in quadrature, the pull of one magnet is at its maximum when that due to the other is zero and *vice versa*.

In standardising the machine the range of stress was measured by means of a standard specimen fitted with a special design of extensometer. The voltage and frequency being measured simultaneously, the calibration constant, k, was determined from the equation $R = k\ (E/f)^2$, where f is the frequency. In regular testing the range of stress was deduced from k, E and f, the last two being the only observations required. The constant, k (which varies only slightly), is dependent on both voltage and frequency, and was therefore determined over a wide range of conditions. It is estimated that the range of stress can be measured within 1 per cent. of accuracy.

When it was required to test a specimen under stresses varying between unequal magnitudes of pull and push, the magnets were still supplied with equal voltages in quadrature, and the additional pull or push was produced by extending or compressing a standardised spring, SS, attached below the armature. Thus we have—

Range of stress = R = (P max. − P min.).

Steady (mean) stress = S = ½ (P max. + P min.).

Lateral guidance for the armature and its attachments is provided in the form of light steel springs, G–G; thus no slide bars are required. The tautness of the guide springs also ensures absence of bending stress in the specimen, such as otherwise might have been produced by any slight eccentricity of the pulls.

The combined stiffness of the several springs is adjusted, according to the frequency of pulsation required in the test, so that the force absorbed in overcoming the inertia of the comparatively massive armature is contributed by the deflection of the springs. This adjustment is very desirable, since otherwise a correction of some 5 per. cent. would have had to be applied in calculating the stress range in the specimen. The adjustment is readily effected by setting the springs to such a length that the moving system, without a specimen in place, vibrates in resonance with the magnetic pull. No resonance exists after the specimen is inserted, as its stiffness is many times greater than that of the springs. The principles of this adjustment, as also of the three different methods of calibration employed, are described more fully in the papers already mentioned.

ALTERNATING STRESS TESTING MACHINES

Fig. 1.

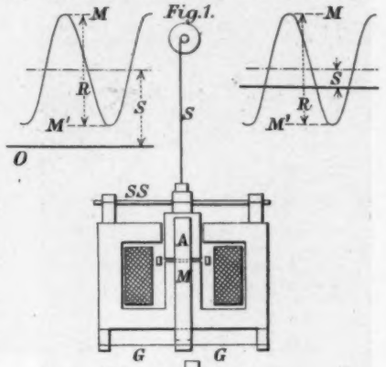


Fig. 2.

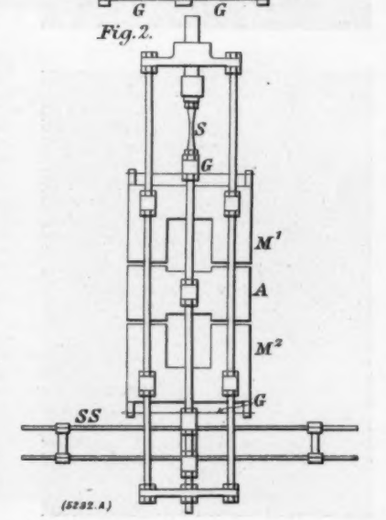


Fig. 3. FATIGUE TEST-PIECE.

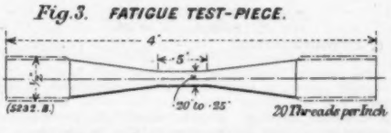


Fig. 3 shows the form of test-piece used, 4 in. in length, with a cylindrical mid-portion ¼ in. in length, of $\frac{1}{16}$ in. to ⅛ in. diameter, according to the strength of the metal. The screwed ends, of ⅛ in. diameter, run down to the cylindrical part in a fine taper with very smooth transition curves. As is well known, any sudden change of section tends to localise stress and thereby accelerate fatigue. It was found that some care was required in machining the specimens, to ensure that fracture occurred in the mid-length and not on the transition curves.

The specimens were finished with fine emery, but were not lapped or burnished. Fig. 12, page 317, shows the result of using coarse emery. Cracks developed from surface scratches under stresses perceptibly lower than the normal. It appears that the current practice of polishing the surfaces of high-speed connecting rods—and other parts subjected to dangerous fatigue stresses—is well justified.

In testing each metal investigated a number of similar test-pieces were prepared and tested under different ranges of variation of stress. During the life of each specimen the maximum and minimum stresses and the frequency were kept constant. In comparing different metals, the standard frequency of 2,000 cycles per second were adopted; but in certain experiments higher frequencies were employed, with results which will be described. An automatic device was arranged to stop the electric generator when the test-piece was fractured, so that the life of the test-piece could be measured by counting the number of revolutions made by the alternator. In ordinary tests, in which the test-pieces broke without elongation, little supervision was required to maintain constant voltage and frequency, but when the metal extended in a ductile manner continuous attention was required to measure the elongation and maintain a constant width of air-gap between the pole faces of the magnets.

Brasses Investigated.—The brasses used in these experiments were obtained from commercial supplies in the form of ¾-in. bolt-staves. They were not specially manufactured for the purpose, and may be regarded as typical of rolled and extruded brasses of their respective analyses, given in the above table. The characteristic microstructures are shown in Figs. 4 to 7, on page 316. Samples I and II were tested as received and again after annealing (IA and IIA); samples III and IV only in the condition in which they were received.

—	Structure.	Figs.	Copper.	Zinc.	Tin.	Iron.	Lead.
I. Muntz metal	α + β	4	58.0	41.2	trace	0.80	—
II. Naval brass	α + β	5	58.5	40.1	0.50	0.87	—
III. Naval brass	α + —	6	66.3	32.2	1.2	—	0.25
V. Phosphor-brass	α	7	—	—	—	—	—

Tensile Tests.—Tensile tests were carried out on the samples as received, and on the two samples Nos. IA and IIA after annealing. The results are given in the following table:—

Metal.	I.	IA.	II.	IIA.	III.	IV.
Yield, tons per square inch	15.0	11.0	14.5	11.0	13.0	23.0
Ultimate strength per square inch	33.3	26.2	28.7	26.2	23.2	28.4
Elongation, per cent. ..	29.7	28.3	26.8	30.7	28.0	49.0
Reduction of area, per cent.	31.0	30.0	28.0	32.0	30.0	63.0

Except in the case of No. IV there was little local elongation or reduction of area at fracture; hence the percentage elongations given above are applicable for any gauge-length. In sample No. IV the local elongation was considerable, the total elongation, expressed in terms of D and L, being 39 + 100 D/L per cent., corresponding to 49 per cent. on 10 diameters. The stress-strain diagrams for the several samples are given in Figs. 8 to 11, page 316, graphs T and T_a, the latter symbol marking the curves for the annealed samples.

Alternating Stress Tests.—Under alternating stresses varying between equal intensities of pull and push, with a frequency of 2,000 per minute, the behaviour of these brasses was very similar to that of mild steel tested in the same manner. The limiting fatigue stresses were, however, somewhat lower, and the results, in general, somewhat more consistent between different specimens of the same sample. It was observed that the fractures were, as a rule, somewhat more regular in profile.

When the range of stress was comparatively high the metal warmed and soon failed by cracking on a plane perpendicular to the axis of stress. Under lower ranges of stress the warming became imperceptible to the touch, and the endurance increased to millions of cycles before fracture occurred in the same brittle manner.

Fig. 13, page 317, shows the appearance of the fracture produced in sample No. II. A smooth crack traverses part of the cross-section, of which the remainder has finally torn away in a semi-ductile manner. The relative areas covered by the crack and by the tear vary between the different samples, the ratio between the two being highest in Nos. I, II, IV, IA, IIA, lower in No. III, and lower still (about 1 : 10) in certain cast brasses tested in a similar manner.

Figs. 14 and 15, page 317, show the profiles of the cracks produced by fatigue in samples III and II respectively. The broken test-pieces were embedded in soft solder and cut so as to expose a longitudinal section, which was polished and etched with ammonia. In sample No. III the crack is rugged in profile, and appears to have followed the boundaries between the crystals. These boundaries contain an appreciable proportion of lead. In sample No. II the crack is smoother, probably on account of the finer structure. It is remarkable that the cracks produced in brasses of sound structure show the branches that are commonly observed in mild steel.

Although experience shows that the development of cracks in marine shafting, &c., is very gradual, so that such shafts may safely be retained in service for some time after the first appearance of a fine crack, it was observed that under test conditions the growth of the crack was exceedingly rapid. The theory of elasticity indicates that the rate of the growth of a crack, once formed, should be rapid on account of the local concentration of stress at the edge of the fissure. That this is not so in practice may be due to the variability of the stresses at work. Under the conditions of test the crack develops so rapidly that only in a few instances has it been observed prior to fracture.

Figs. 8 to 11 show also the graphs R–RA, giving the results of fatigue tests. The ordinates give the ranges of stress (double the maximum intensities) imposed on the specimens used in individual tests, and the abscissæ

* Paper read before the Institute of Metals, Wednesday, September 19, 1917.

† British Association paper, 1912, ENGINEERING, November 22, 1912; and West of Scotland Iron and Steel Institute, November 12, 1915.

the endurances, in millions of cycles, elapsing prior to fracture. The scale on which the diagrams are plotted renders it unnecessary to quote figures for the large number of tests carried out. The conclusions are summarised in the following table :—

Sample Number.	I.	Ia.	II.	IIa.	III.	IV.
Range R1 ..	25.5	22.0	26.7	24.0	18.1	30.5
Range R2 ..	25.0	22.0	25.3	23.6	17.5	—
Ratio x ..	0.383	0.437	0.465	0.458	0.390	0.540

Range R1 is that producing fatigue after 1,000,000 cycles, and R2 that for 2,000,000. The ratio x is that between the limiting maximum stress for 1,000,000 cycles and the ultimate tensile strength of the sample.

The ratio between the limiting range and the yield-point has not been quoted, since the yield point is somewhat indefinite in such materials. Ratios between the fatigue limit and the primary elastic range have also been omitted, since the author has not been able to verify any of the relations between these quantities hitherto suggested.

——	Sample V.	Sample VI.
Yield-point, tons per square inch ..	27.5	19.0
Ultimate strength, per square inch ..	40.5	32.0
Elongation, per cent.	15.0	29.0
Elastic limit, tension	20.0	13.0
Elastic limit, compression	9.0	7.0
Primary elastic range	29.0	20.0
Range R 500,000	22.0	24.0
Range R 1,000,000	17.0	21.0
Ratio x	0.210	0.328

As an illustration of the absence of direct proportionality between the limiting fatigue and the primary elastic range in tension and compression, a comparison may be made between two manganese-aluminium-iron brasses of high tensile strengths (both sand-castings). The best results obtained from these samples are tabulated at the bottom of the preceding column.

In sample V the fatigue range has not reached its maximum when the endurance is 1,000,000 cycles, but is already less than the primary elastic range. In sample VI the fatigue range for 1,000,000 cycles is somewhat greater than the primary elastic range.

On the whole the most regular, and certainly the most convenient, ratio of comparison appears to be the ratio between the limiting fatigue stress and the ultimate strength of the metal. The use of this ratio has the advantage of conveying useful information without implying the existence of any definite physical relation between the two qualities.

The above experiments illustrate, although they cannot prove, a simple working rule which seems to have few exceptions—viz., that the value of the ratio x is highest in those metals which show considerable reduction of area at fracture in the tensile test. It is not intended to imply that a physical connection exists between the two, except in so far as both may be dependent on the same characteristics of the micro- and submicro-structure. The rule applies for steels as well as for brasses; ; thus the ratio x and percentage reduction of area are lower in wrought-iron than in mild steel, doubtless on account of the presence of slag. In ingot iron the values of the two are higher than in either of the above metals ; and in alloyed steels that show considerable resistance to fatigue high tensile strength is generally associated with great reduction of area at fracture. In steels tested in the manner above described the value of the ratio x generally varies between 0.60 in ingot iron and the best mild steel, and 0.40 in high tensile and tool steels in annealed condition.

Stresses varying between Unequal Pull and Push.—Sample No. II was used in a series of experiments to ascertain the relation between the limiting fatigue range and the ratio between the (unequal) maximum intensities of direct pull and push. Six series of tests were carried out with different intensities of mean (steady) stress. In each series the mean stress was maintained constant, while the range of alternation was varied for successive specimens. The duration of the tests lasted from a few cycles up to 2,000,000, and other tests were continued beyond this stage without fracture. The curves obtained, plotted as under, were found to be asymptotic to values which may be regarded as nearly equal to the fatigue limits below which fatigue would not occur after an infinite number of repetitions of stress. These values are given in the next table.

These figures are plotted in Fig. 16, the abscissæ giving the mean stress, and the ordinates, for graph R

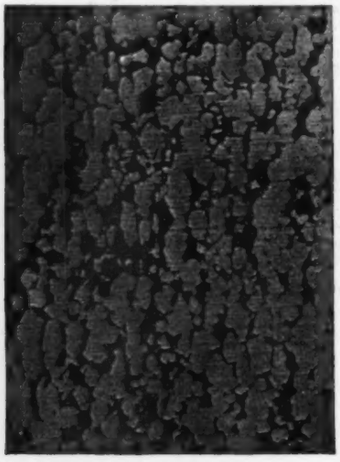


FIG. 4. Sample I. ×200.
FIG. 5. Sample II. ×200.

FIG. 6. Sample III. ×200.
FIG. 7. Sample IV. ×400.
Longitudinal sections, etched with ammonia.

Fig. 8. TESTS OF SAMPLE N°I.

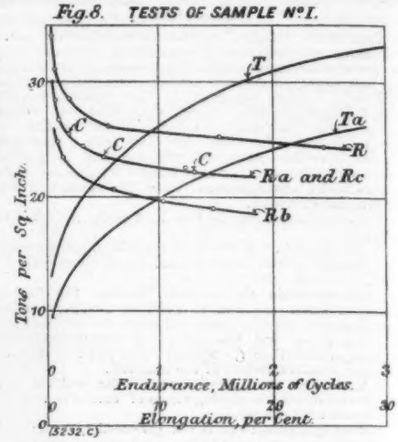


Fig. 9. TESTS OF SAMPLE N°II.

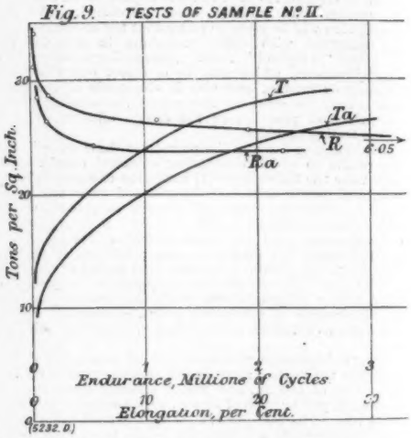


Fig. 10. TESTS OF SAMPLE N° III.

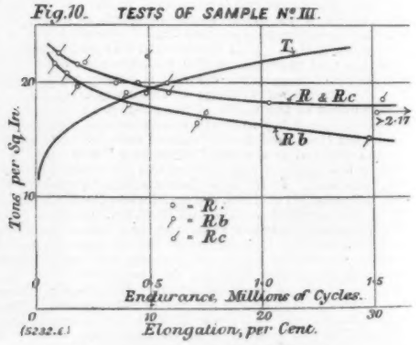
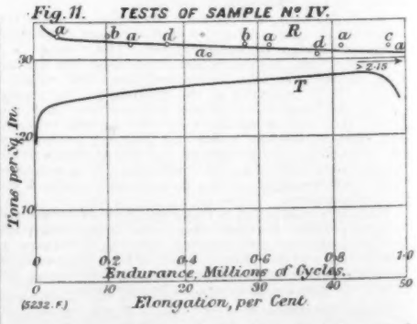


Fig. 11. TESTS OF SAMPLE N° IV.



the limiting fatigue ranges, and for graphs M and M′ the maximum intensities of pull and push. It appears

Series No.	1.	2.	3.	4.	5.	6.
Mean stress, tons per square inch ..	nil	4.0	6.23	7.72	−3.26	−6.0
Range of stress per square inch ..	24.0	21.0	19.2	17.5	27.4	29.6
Maximum pull stress per square inch ..	12.0	14.5	15.8	16.5	10.5	8.5
Maximum push stress per square inch	−12.0	−6.5	−3.4	−1.0	−17.0	−20.5

further increased, failure occurred by ductile elongation before fatigue was developed. And even in series Nos. 3, 4 and 6 the majority of the specimens failed in a ductile manner. Thus we may deduce that the yield-point under pulsating stress is nearly the same as that measured under steady stress.

A number of experiments on the ductile elongation of mild steel, copper and brass wires, under pulsation stresses, were carried out in the smaller testing machine already mentioned.

Fig. 17 represents the results obtained with a soft brass wire (70 : 30), and also tensile tests on the same material. Graphs T and T′ reproduce stress-strain diagrams for tensile tests in Professor Barr's autographic testing machine. The two graphs were obtained with fast and slow rates of loading—viz., 3.2 and 0.13 tons

FIG. 12. Fracture accelerated by scratches.
FIG. 14. Profile of fatigue crack. Sample III. ×200.

FIG. 13. Face of fatigue fracture.
FIG. 15. Profile of fatigue crack. Sample II. ×200.

that, plotted in this manner, the stresses obey a linear law which may be expressed as

$$R = R_0 - k \cdot S$$

hence

$$M \text{ or } M' = (S \pm \tfrac{1}{2} R) = S \pm \tfrac{1}{2}(R_0 - k \cdot S).$$

This result may be compared with Bauschinger's experiments for steel, expressed by "Gerber's parabola." For steels the graph R would be a parabola to the equation

$$R = R_0 - k' S^2,$$

passing through the point $x = U$, where U is the ultimate strength of the material, so that $k' = R_0/U^2$. In the case of the brass investigated it appears that the graph R likewise passes through $x = U$, hence we may write $k = R_0/U$. But in other brasses tested by the author the value of k is less than the above; that is, the lines M and M′ converge more steeply. It appears that the linear relation between R and S is common in brasses and may be accepted as very nearly true.

As explained, the graphs M and M′ represent the limiting conditions of stress above which fatigue occurs by the production of a brittle fracture. But when the range of stress is greater than that represented, and is combined with considerable steady pull or push, failure may also occur by the gradual elongation or compression of the specimen. The greater the mean stress, the narrower the zone in which brittle fracture can occur. It was not possible to continue the experiments beyond the limits given, for when the steady stresses were per square inch per minute. The divergence between the two is only slight, doubtless because in such brasses the effects of "after-train" are less than in many other ductile metals.

The same material was tested under pulsating stresses with frequencies of 5,760 cycles and 3,600 cycles per minute. On account of the lateral vibration produced in wire specimens when the range of stress carried the minimum of the cycle to zero, it was found necessary to maintain a certain finite minimum pull in order to obtain a reliable test. Under pulsating stress, as under steady load, the yield-point was observed to be somewhat indefinite. Above the yield-point, elongation was produced at definite stresses that could readily be measured. In Fig. 17 the maximum and minimum intensities, M and M′ (compare Fig. 1), are plotted on the base of elongation already used for the tensile tests. Comparing the curves, it seems at first sight that the change in frequency has produced considerable effect, but the difference between the maxima for the two frequencies may be attributed to the difference between the two minima employed. By varying the minimum while a test was in progress it was found that any given increment to M′ required a corresponding but smaller increment to M to produce elongation. Careful measurements showed that the increment to M was from one-half to one-third of that to M′. Assuming either of these values, we may deduce from M and M′ the value of an "equivalent" pulsating stress which, with zero as the minimum of its cycle, would produce the same elongation. The approximate locus of this equivalent pulsating stress is represented in the diagram by the curve P, somewhat below M. The ordinates of P are nearly alike for the tests with the different frequencies, and are approximately two-thirds of those of the curves representing the tensile tests.

Figs. 18 and 19 summarise a number of similar tests on soft copper wire. As shown by the graphs T1 and

Fig. 16. FATIGUE LIMITS UNDER UNEQUAL PULL AND PUSH.

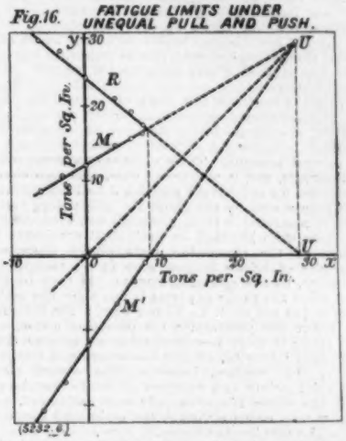


Fig. 17. DUCTILE ELONGATION OF BRASS WIRE.

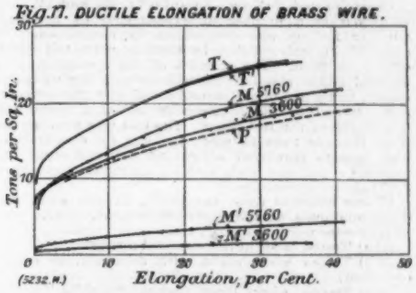


Fig. 18. ELONGATION OF COPPER WIRE UNDER PULSATING STRESS.

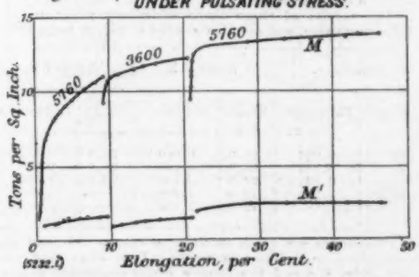
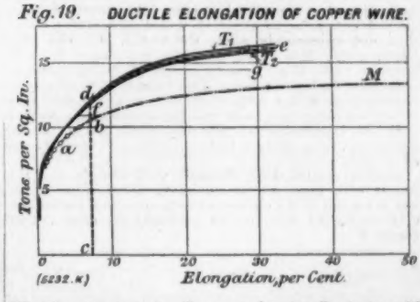


Fig. 19. DUCTILE ELONGATION OF COPPER WIRE.



T2 (the stress-strain diagrams for tensile tests with fast and slow rates of loading), the effects of after-strain are, in this metal, greater than in the brass used in the preceding experiments. Graphs M and M′, Fig. 18, represent an elongation test under pulsating stress. A single specimen was extended, first at 5,760 cycles per minute, then at 3,600 cycles, and finally, to facture, at 5,760 cycles. Allowing for the differences in the minimum stresses M′, the maxima M appear to be closely identical for the two frequencies. The graph M is also plotted in Fig. 19 for comparison with the tensile tests. It was found that, although the yield-point under pulsating stress is nearly equal to that under steady tension, further elongation is produced with considerably less increase of load than in an ordinary tensile test. Also that the ultimate elongation produced in copper is greater under pulsating stress (46 per cent.) than in steady tests on the same material (34 per cent.).

Several experiments were carried out to ascertain whether the elongations produced by the two kinds of stress were of the same nature. A specimen was extended first under pulsating stress up to 7 per cent. strain, and then further tested under steady load. It was found that the new yield-point and the form of the stress-strain diagram (*o, a, b, c, d, e*, Fig. 19) were the same as if an equal percentage elongation had been produced by an initial steady load. Conversely, specimens strained initially under steady load showed the same yield-point and diagram under pulsating stress as if the initial elongation had been due to pulsating stress.

It was suggested that the graph M, or more probably that corresponding to the equivalent pulsating load P, might constitute the limit of elongation produced by long-continued after-strain under steady load. A number of specimens were therefore loaded with different constant weights and allowed to extend during a period of several months. Their elongations were measured at intervals, and it was found that, although elongation continued for at least six months, it had not yet attained that represented by the graph M. (Cf. points *f* and *g*.)

It is remarkable that, although some 500,000 cycles of stress were imposed on individual specimens in the course of the elongation tests above described, no examples of brittle fatigue were found except, in rare instances, at the end attachments. It may be inferred that when the range of stress is less than the maximum tension (80 per cent. to 90 per cent.), the fatigue limit lies above the yield-point for pulsating stress. When the range is more nearly equal to or greater than the maximum intensity, fatigue occurs prior to ductile elongation. In practice, however, the actual range at particular points in a complex structure may be greater than the mean range as generally estimated, so that fatigue may occur although the estimated range is well below the maximum tension.

Corrosion and Fatigue.—Samples IA, III and IV were employed in a number of experiments to ascertain whether fatigue was accelerated by the presence of different corrosive fluids in contact with the metal during the test. The surfaces of the specimens were finished in the standard manner by grinding with fine emery, and a pad of cotton moistened with the corrosive and exposed to the atmosphere was tied round the mid-length of the test-piece. The pad was remoistened from time to time to meet the loss by evaporation. The stresses employed alternated between equal intensities of pull and push, with the standard frequency of 2,000 cycles per minute.

In one series of tests sample No. IA was used, with dilute ammonia as the corrosive reagent. Three sets of specimens were compared, viz. :—

(R *a*) Tested in air in the standard manner.

(R *b*) Tested while moist with ammonia, as above described.

(R *c*) Tested after three hours "etching" with ammonia in air, followed by washing and drying to remove the corrosive.

The results of these three series are given in the following table, and are also plotted in Fig. 8, page 316.

Series R *a*.		Series R *b*.		Series R *c*.	
Range.	Endurance.	Range.	Endurance.	Range.	Endurance.
28.6	0.064	24.9	0.080	25.6	0.192
26.7	0.088	23.6	0.128	23.6	0.480
24.4	0.32	20.8	0.784	22.1	1.264
22.6	1.22	19.6	1.008	—	—
—	—	19.0	1.456	—	—

The ranges are given in tons per square inch, and the endurances in millions of cycles. It is clear that the two series R *a* and R *c* form a single consistent graph, indicating that superficial etching with ammonia, when carried out *prior* to the test under alternating stress, does not appreciably affect the result. On the other hand, series R *b* shows that the endurance is much reduced when the corrosive action of the ammonia is operative *during* the test. The form of the graph R *b* indicates that the fatigue limit has not reached its minimum value even at 19 tons per square inch; hence it may be expected that the continued action of the corrosive might produce fatigue under still lower ranges of stress.

Similar results were obtained with sample No. III, tested with ammonia as corrosive. Tests were carried out in air (series R), moistened with ammonia (series R *b*) and moistened with dilute hydrochloric acid (1 : 40) (series R *c*).

Series R.		Series R *b*.		Series R *c*.	
Range.	Endurance.	Range.	Endurance.	Range.	Endurance.
21.7	0.192	21.7	0.096	22.6	0.112
20.1	0.432	20.8	0.144	21.7	0.224
19.9	0.360	19.7	0.192	21.1	0.502
19.0	0.496	19.0	0.408	19.9	0.592
18.04	1.04	18.04	0.416	19.0	0.592
17.22	2.17*	17.22	0.760	18.3	1.552
—	—	16.37	0.720	—	—
—	—	15.0	1.488	—	—

* Unbroken.

These results are plotted in Fig. 10, page 316. It is remarkable that although fatigue has been accelerated by the presence of ammonia during the test, no such effect has been produced by dilute hydrochloric acid. On the contrary, the endurances of specimens moistened with hydrochloric acid were generally greater than those of dry specimens under the same ranges of stress.

The phosphor-bronze (sample No. IV) was likewise tested with different corrosive reagents—ammonia (*b*), dilute hydrochloric acid (1 : 40) (*c*), and sea-water (*d*). The results, plotted in Fig. 11, page 316, are given in the following table :—

Series R.		Series R *b*.		Series R *c*.		Series R *d*.	
Range	Endurance	Range	Endurance	Range	Endurance	Range	Endurance
33.2	0.064	33.1	0.192	32.0	0.944	32.0	0.352
32.6	0.816	32.0	0.560	—	—	30.8	0.752
32.0	0.256	—	—	—	—	—	—
32.0	0.624	—	—	—	—	—	—
30.8	0.464	—	—	—	—	—	—
29.6	2.15*	—	—	—	—	—	—

* Unbroken.

The results are not quite so consistent as in the preceding experiments with brasses; but, on the other hand, the difference between the ranges for long and short endurance is smaller. It is clear that no appreciable acceleration of fatigue has been produced by any of the corrosive reagents employed.

As the action of ammonia is most evident in brasses containing the β constituent and is absent in the phosphor-bronze of pure α structure, and as ammonia is well known as an etching reagent that attacks β, it may be inferred that the acceleration of fatigue produced in $\alpha + \beta$ brasses in the presence of ammonia is due to the decomposition of the β constituent. But the phenomena are not peculiar to such brasses, for the author has observed that fatigue is accelerated in the same manner in mild steel and other metals exposed to corrosion by acids, sal-ammoniac and salt water. Where the surface of the specimen has been appreciably roughened by corrosion prior to testing, the endurance has naturally been reduced. But, as has been shown above, this effect is generally small in comparison with the reduction that occurs when the surface is moistened with the reagent during the test. The same effect has been observed in practice. Thus railway carriage axles have been found to be particularly liable to fatigue, distinct from corrosion, where exposed to the acid effluents from lavatory compartments. And in marine experience the author has observed many instances of abnormally rapid fatigue in steel structures immersed in salt water and subject to vibration. The fracture of marine propeller blades may likewise, in part, be due to fatigue accelerated by the enhanced corrosive properties of water containing gases in solution. Such gases are doubtless liberated, in the nascent state, by the sudden reduction of pressure produced near the leading edge of the propeller blade.

On the other hand, fatigue may very readily occur in parts that have suffered appreciable corrosion prior to the application of the stresses that effect the failure. Figs. 20, 21 and 22 (below) show an example of this in a $\frac{3}{4}$-in. manganese-bronze (sea-water) valve-spindle. The longitudinal section, polished and etched with ammonia, shows that the exterior of the spindle has suffered corrosion and that the affected area has reached

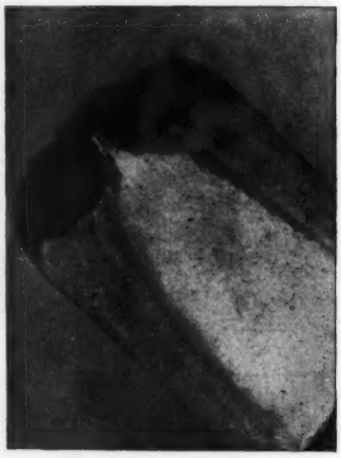


FIG. 20. Longitudinal section, corroded valve spindle.

FIG. 22. Sound and corroded β crystals, mixed with α. ×200.

FIG. 21. Fatigue crack in corroded metal. ×200.

FIG. 23. Fatigue fracture of Bessemer steel.

the centre of the bar. Fracture occurred (without local elongation) through the corroded section. Fig. 21 shows the extremity of one of the branched cracks, threading its way through the spongy copper spaces between the as yet unharmed α crystals. Fig. 22 shows the line of demarcation between the corroded and sound areas. As is now generally recognised, the β constituent is gradually reduced by the action of sea-water to spongy copper, leaving crevices through which the water percolates into the mass.

The phenomena described in the foregoing experiments are distinct from those of normal corrosion, in that they occur only locally and with much greater rapidity. Chemical action is doubtless accelerated by strain in the crystals, even below the elastic limit; and the alternation of stress facilitates the formation of crevices and progressive corrosion throughout the mass. It is generally held that, according to the "amorphous" theory of ductile strain, fatigue is associated with the conversion of a portion of the metal from the crystalline

to the amorphous state. But it appears that this explanation covers only one of several possible changes of structure that may cause fatigue. The change of state involved need not necessarily be of the nature of an allotropic change, but may be of the nature of a chemical combination, leading to the formation of an oxide or salt.

As the endurance under a given range of stress is occasionally less when the specimen is dry and exposed to air than when it is covered with a layer of reagent, it appears that the atmosphere, as well as fluid reagents may act chemically upon the metal. The faces of the fatigue cracks formed in brass and in mild steel commonly show signs of oxidation. Fig. 23 (page 318) shows this effect in a specimen of Bessemer steel broken by fatigue. The crack changes in colour as it enters the metal, and is darkest at the starting edge. The colour appears to be due to a film of black oxide of iron, and does not further develop after fracture until eventually rusting sets in. The discoloration can hardly be due to rise of temperature in the ordinary sense, because the observed general rise was very slight. And if it were due to momentary rise of temperature during the process of fracture, we might expect the colour to grow deeper as the crack enters the metal with steadily increasing speed.

Although the foregoing experiments raise points that can only be settled by further investigation, and can therefore only be regarded as preliminary to others in which a wider range of materials will be examined, it is hoped that they possess a practical as well as a philosophic interest. The author hopes on another occasion to deal with the more theoretical thermo-dynamic considerations governing the failure of metals by elongation and by fatigue. The experiments have been carried out in the Engineering Laboratories of the University of Glasgow and of the Royal Naval College, Greenwich. To Emeritus Professor Archibald Barr, D.Sc., and to Professor J. B. Henderson, D.Sc., the author is indebted for the opportunities afforded in these colleges, and for encouraging interest.

CONCRETE SHIPS.—A movement is on foot among prominent business men of Montreal, says *The Iron Trade Review*, Cleveland, O., to undertake the construction of concrete steamships. The formation of a syndicate to establish the industry has been promoted by the Atlas Construction Company, and it is understood that the necessary capital has been secured. Plans for the first vessel have been prepared. It will be 200 ft. in length, and the thickness of the hull will be from 3 in. to 5 in. The cost is estimated at something less than 100,000 dols. The venture is largely experimental, and should it prove successful, several companies are ready to enter upon this line of business.

CRACKING HYDROCARBON VAPOURS BY ELECTRICITY.—We read in *Electrical World*, New York, that a process which aims to obtain by means of an electric discharge a greater yield of fixed gases from hydrocarbon vapours is the development of J. G. Davidson and R. W. Ford, Vancouver, B.C., Canada. Patent No. 1,229,042 has been granted covering the discovery that by passing such vapours through an electric brush discharge field the amount of non-condensible gases is increased. In actual tests it is claimed that by this process the amount of CH_4 in the gas has been increased from about 25 per cent. to approximately 40 per cent., while the amount of $C_n H_{2n}$ was increased from between 7 per cent. and 10 per cent. to between 20 per cent. and 23 per cent. Ordinarily the gas is conducted through a plurality of conduits formed as vertical pipes, connected at their lower ends to a supply header and at their upper ends to an outlet header, the discharge electrode being formed as wires hung axially in the pipes from an insulated support. The pipes are grounded and the electrodes are connected by a wire to a mechanical rectifier of the usual rotary type included in the high-tension circuit of a step-up transformer, the rectifier being connected to ground.

REFUSE WOOD AS FUEL.—Our contemporary *Power*, New York, refers to recent arrangements made for using refuse wood as fuel by the Oregon Power Company, and the Booth Kelly Lumber Company, of Springfield, Ore. The latter company operates a large sawmill and planing mill, and by means of conveyors and blower systems transmits a portion of the refuse wood to the adjacent plant of the central-station company; the power company pays 0.005 dols. per kilowatt-hour at the switchboard to the lumber company for all energy generated, and the lumber company in turn pays 0.009 dol. per kilowatt-hour for the first 1,000,000 kw.-hour used in each current year, and 0.008 dol. per kilowatt-hour for all over this amount. The contract further calls for a minimum usage on the part of each party to the agreement. For instance, the power company agrees to purchase sufficient fuel to generate a minimum of 3,000,000 kw.-hours per annum in excess of the amount used by the lumber company, and the latter agrees to use a minimum of 1,500,000 kw.-hour per annum to operate 76 motors in and about its mills. The steam required by the dry kilns, for heating the offices and operating devices about the sawmill for which electricity has not as yet taken the place of steam, is secured from the Oregon Power Company. This steam is used in such quantities as to require an 8-in. pipe, with boiler pressure of 150 lb., to supply it, and is purchased at a flat rate of 45 dols. a month. In other words the lumber company pays 45 dols. a month for the use of the boilers of the power company and furnishes the fuel.

A COMPARISON OF THE ACTIVATED SLUDGE AND THE IMHOFF TANK-TRICKLING FILTER PROCESSES OF SEWAGE TREATMENT.*

By HARRISON P. EDDY.†

(*Concluded from page 290.*)

Activated Sludge Plant.—The estimated cost of the activated sludge plant is given in Table 2. In addition to the features already described, it will be noted that several items have been included to make the plant complete. As stated in the case of the trickling-filter plant, the item of 25,000 dols. for land includes about 117 acres. It may not ultimately prove necessary to isolate the activated sludge plant, in which case a credit in favour of this plant should be made on account of the small area of land required. In this case, as in the other, 15 per cent. has been added to cover the cost of administration and engineering charges. It will be seen that the total cost of the activated sludge plant is 313,880 dols., which for a population of 55,000 persons is equivalent to 5.71 dols. *per capita*, and 57,100 dols. per 1,000,000 gallons per day.

TABLE 2.—*Estimated Cost of Activated Sludge Plant.*

—	Cost, Excluding Engineering and Administration. Total.	Unit Cost, excluding Engineering and Administration. *Per Capita.*	Unit Cost, excluding Engineering and Administration. Per 1,000,000 Gallons per Day.
Grit chamber and screen ..	10,000	0.18	1,818
Venturi meter and chamber ..	3,000	0.05	546
Sewage aeration tanks ..	78,100	1.42	14,200
Sludge aeration tanks, including air lifts	17,500	0.32	3,180
Sedimentation tanks, including air lifts	8,300	0.15	1,510
Air compressing equipment ..	22,600	0.41	4,110
Air meters—two	700	0.01	127
Air washer—one	600	0.01	109
Power-house	29,700	0.54	5,400
Sludge beds, including underdrains	31,400	0.57	5,710
Conduits, pipe lines and overflow	10,000	0.18	1,818
Effluent drain	1,300	0.02	236
Roadways	8,300	0.15	1,510
Laboratory building and equipment	15,200	0.28	2,760
Grounds, trees, planting, &c. ..	1,700	0.03	309
Miscellaneous work, 4 per cent. of total, excluding land ..	9,540	0.17	1,735
Land	25,000	0.45	4,540
Total	272,940	4.94	49,618
Add 15 per cent. for engineering and administration ..	40,940	0.77	7,482
Grand total	313,880	5.71	57,100

For 55,000 persons = 5.71 dols. *per capita.*
For 5,500,000 gallons per day = 57,100 dols. per 1,000,000 gallons per day.

COST OF OPERATION.

Trickling-Filter Plant.—An estimate has been made of the cost of operation of the trickling-filter plant, based principally on the experience at Fitchburg for the years 1915 and 1916. From data furnished by David A. Hartwell, chief engineer, deductions have been made for certain expenditures pertaining to construction rather than operation. The items for 1916 (with estimates for November, the last month of the fiscal year) are shown in Table 3, from which it appears that the total cost of operation has been 11,250 dols., which is equivalent to 10.28 dols. per 1,000,000 gallons treated, averaging 3,000,000 gallons per day, or 35 cents *per capita*, on a basis of 32,500 persons actually connected. The total population in 1915 was about 39,656.

Similar figures for the Gloversville trickling-filter plant, obtained through the courtesy of Harry J. Hammer, city engineer, show the following costs of operation per 1,000,000 gallons of sewage treated:—

Year.	Annual Cost of Operation. Per Million Gallons Treated. Dols.	Per *Capita.* Dols.
1913	5.16	0.24
1914	5.92	0.27
1915	5.72	0.26

It should be stated here that these expenditures are limited to the barest necessities. No chemical supervision nor other refinements which can be avoided are permitted.

The estimate of annual operation cost of the hypothetical Imhoff tank-trickling filter plant to serve a population of 55,000 is given in Table 4.

TABLE 3.—*Estimated Annual Cost of Operation of Fitchburg, Mass., Imhoff Tank-Trickling Filter Plant, for the Year* 1916.

	Dols.
General, including administration ...	1,800
Laboratory	1,700
Grit chamber	900
Imhoff tanks	1,700
Trickling filters	1,100
Secondary tanks	900
Sludge beds	800
Care of grounds	1,250
Miscellaneous	1,100
Total	11,250

3,000,000 gallons per day = 1,095,000,000 gallons treated = 10.28 dols. per 1,000,000 gallons.

32,500 persons = 0.35 dols. *per capita.*

TABLE 4.—*Estimated Annual Cost of Operation of Typical Imhoff Tank-Trickling Filter Plant.*

	Dols.
General, including administration ...	2,200
Laboratory	1,700
Grit chamber	1,650
Imhoff tanks	3,120
Trickling filters	2,020
Secondary tanks	1,650
Sludge beds	1,470
Care of grounds	1,250
Miscellaneous	2,020
Total	17,080

5,500,000 gallons per day = 2,005,000,000 gallons treated = 8.50 dols. per 1,000,000 gallons.

55,000 persons = 0.31 dols. *per capita.*

Activated Sludge Plant.—The estimated annual cost of operation of the activated sludge plant is shown in Table 5. Nearly half of the annual operating cost is for electric power, required for compressing the air. It was estimated that in addition to the air required for sewage aeration, one-fifth as much would be required for sludge re-aeration and for operating the air-lift pumps. The total annual cost of operation amounts to 40,140 dols., which is equivalent to 20 dols. per 1,000,000 gallons treated, or 73 cents *per capita*, based on 55,000 persons.

The item for power is estimated on the assumption that it can be obtained at 1 cent per kilowatt-hour. For many places this is a low price, while for others it is high. Surely it is low enough for use in computing the cost of power in most places upon a project which is to be operated for a generation in the future.

TABLE 5.—*Estimated Annual Cost of Operation of Typical Activated Sludge Plant.*

Item.	Dols.	Annual Cost. Dols.
General, including administration		2,200
Laboratory		1,700
Grit chamber		1,650
Tank treatment—		
One engineer foreman at 4 dols. per eight-hour day, 312 days	1,248	
Three engineers at 4 dols. ...	3,744	
Four labourers at 2.50 dols....	3,120	
Repairs	1,278	
		9,390
Sludge drawing and disposal—		
Foreman, part time	375	
Two labourers at 2.50 dols., 312 days each	1,560	
One team at 6 dols., 312 days	1,872	
Supplies and repairs	603	
		4,410
Electric power at 1 cent. per kilowatt-hour...		17,040
Care of grounds		1,250
Miscellaneous		2,500
Total		40,140

5,000,000 gallons per day = 2,005,000,000 gallons treated = 20 dols. per 1,000,000 gallons.

55,000 persons = 0.73 dols. *per capita.*

COMPARISON OF COSTS.

For the final comparison of costs the interest and depreciation have been computed for both plants, and the total annual cost, made up of operating expenses and interest and depreciation, has been capitalised at 4 per cent. and added to the construction cost, Table 6. The

TABLE 6.—*Comparison of Costs of Imhoff Tank-Trickling Filter Plant and Activated Sludge Plant.*

Item.	Trickling-Filter Plant. Dols.	Activated Sludge Plant. Dols.
Operating expenses	17,080	40,140
Interest and depreciation*	26,760	19,780
Total annual cost of treatment ..	43,840	59,920
Total annual cost of operation per 1,000,000 gallons	21.84	29.85
Total annual cost of operation *per capita*	0.80	1.09
Expenses capitalised at 4 per cent. ..	1,096,000	1,498,000
Construction cost	431,710	313,880
Total	1,527,710	1,811,880
Difference	—	284,170

* Interest at 4 per cent.—depreciation sinking fund at 2½ per cent.

result is decidedly in favour of the Imhoff tank-trickling filter plant, in spite of the fact that the estimates of operation of the activated sludge plant have been kept low, probably lower than is justified, that there might

* Paper (somewhat abbreviated) read before the Western Society of Engineers, U.S.A.

† Of Metcalf and Eddy, Boston and Chicago.

be no danger of inflating this cost to the disadvantage of the new process. To eliminate this difference it will be necessary to decrease the operating expenses of the activated sludge treatment by about 11,000 dols., or to decrease them a portion of this amount and, in addition thereto, to decrease the construction cost materially.

A reduction in the price of power from 1 cent to 0.6 cent per kilowatt-hour, the price at which it is estimated power can be purchased at Milwaukee, would effect an annual saving of 6,816 dols. For a plant only large enough for 55,000 persons it is doubtful if power below 1 cent per kilowatt-hour can be procured in many places.

It is not unlikely that improvements in the methods of diffusion and of holding the air for a longer time in contact with the sewage may result in a decrease in the quantity of air required. This would result in a decrease in cost.

At the present time much attention is being given to methods of converting the sludge into marketable fertiliser. There is reasonable agreement among investigators that activated sludge contains a greater proportion of fertilising ingredients than the sludges obtained from most other processes of sewage treatment. If the sludge can be converted into commercially dry powder containing only 10 per cent. moisture, there is good evidence of a market for it at a moderate price.

If the cost of preparation and sale of sludge should be no more than the return from such sales, the reduction in the foregoing estimates of operation and construction would be 5,030 dols. and 36,000 dols. respectively. If this process should be even more successful and a net profit of 2 dols. per ton or, say, 1 dol. per 1,000,000 gallons, should be derived, the saving thus effected would amount to :—

	Dols.
Profit on sludge	2,007.50
Cost of sludge disposal as per previous estimate	5,030.00
Interest and depreciation on sludge beds...	2,270.00
Total	9,307.50

In addition to this annual saving there would be also the saving in investment cost of 36,000 dols.

Even this profit and saving would not be enough to reduce the cost of the activated sludge process to that of the Imhoff tank-trickling filter process, but the net profit of 1 dol. per 1,000,000 gallons may be substantially exceeded. In any event this subject should receive, as indeed it is receiving, most careful investigation.

It may be argued that greater economy will be possible in the large plants than in the typical plant designed to serve 55,000 persons. This is undoubtedly true, but it is also true of the trickling-filter plant. The proportionate saving in the cost of the activated sludge plant, however, may be somewhat greater.

Further development, particularly in the direction of reducing the quantity of air required and improving means of distribution, may result in a reduction of construction cost. It seems more probable, however, that the cost of construction will be increased, and in any event there should be no reduction in construction cost at a sacrifice in efficiency.

In spite of the fact that it appears to be somewhat more expensive than other processes, the activated sludge treatment should not be rejected on the ground of cost without giving full consideration to its advantages. It may be that as an oxidising process it will always be more expensive than the trickling filter, but it may have advantages more important than this disadvantage.

Advantages and Disadvantages of the Two Processes.

Relative Areas of Land.—If it be assumed that the sludge from the activated sludge process is to be dried and disposed of by means of sludge beds, the total area of land used for the activated sludge plant will not differ greatly from that actually used for the trickling-filter plant.

The areas utilised for several trickling-filter plants, including a reasonable allowance for walks, drives and general purposes, are shown in Table 7.

Table 7.

Location of Plant.	Area of Land Required for Plant. Acres.	Area of Trickling Filters.	Average Depth of Stone in Trickling Filters.
			ft. in.
Fitchburg, Mass.	11.8	2.07	10 3
Schenectady, N.Y.* ..	19.0	6.1	4 7½
Gloversville, N.Y.	13.5	3.07	4 7½
Typical trickling-filter plant, estimated	11.8	2.75	10 3

* Original design ; only one-half plant built.

The estimated area required for the typical activated sludge plant is 10 acres, or nearly 2 acres less than that required for the typical trickling-filter plant. If some other form of sludge disposal were used, the area would be materially reduced. In the second annual report of the Milwaukee Sewerage Commission it is stated that the ground area required for the Milwaukee activated sludge plant is 0.4 acre. This plant is capable of treating 1,620,000 gallons of sewage per day, but the area given makes no provision for sludge disposal, and practically nothing for walks, drives and other features to be expected in an ordinary, complete plant. As already stated, the activated sludge plant may have some advantage in not requiring as much land for isolation as the trickling-filter plant. The corresponding reduction in cost would be to the advantage of the former.

Loss of Head Necessary in Plant.—One of the important advantages of the activated sludge process is the small loss of head required for the passage of the sewage through the plant. The resulting saving in cost of sewerage works such as pumping stations and long outfall or intercepting sewers may be sufficient to make the adoption of the activated sludge process imperative. The amount of head lost in several trickling-filter plants is shown in Table 8.

Table 8.—*Head Lost in Trickling-Filter Plants.*

Location of Plant.	Head Lost. Feet.
Columbus, Ohio...	25.34
Fitchburg, Mass.	25.40*
Gloversville, N.Y.	21.40
Schenectady, N.Y. (original design) ...	13.70
Schenectady, N.Y. (actual construction)	14.65
Washington, Pa.	16.50
Philadelphia, Pa.	25.25
Atlanta, Ga., Peachtree Creek Works	20.00

* Actual is 42.1 ft., due to topography.

From this table it will be seen that the head required for a trickling-filter plant varies from 14 ft. to a little over 25 ft. The Milwaukee 1.62 million gallon plant requires 0.3 ft. between the inlet to the sewage aeration tanks and the outlet of the sedimentation tank. In addition to this some loss should be added for the grit chamber and screens, but, in any event, a total loss of 1 ft. to 2 ft.. would appear to be ample.

Odours.—There is some sentiment hostile to an Imhoff tank-trickling filter plant because of the fear of the dissemination of objectionable odours. That objectionable odours are noticeable in the immediate vicinity of such plants cannot be denied. On the other hand, there is good evidence that they are not noticeable except very close to the treatment plants.

The activated sludge plant appears to have some advantage in this direction. Odours may be noticeable in the immediate vicinity of the aeration tanks, and it is possible that objectionable odours may be given off from some portions of the sludge-drying and handling process, whatever it may ultimately be. It is probable, however, that the danger from this source will be less than from the Imhoff tank-trickling filter plant.

Moth Flies.—The moth flies, so prevalent at certain seasons of the year, are quite objectionable close to the filters, although they are rarely found more than a few hundred feet away from them. While this cause of annoyance may be kept under reasonable control, it is doubtful if it can be wholly eliminated. The activated sludge plant does not seem to be a suitable breeding ground for these pests, and therefore has an advantage over the filter.

Quality of Effluents.—There is no doubt that the activated sludge process is capable of producing a more highly oxidised effluent than the trickling filter, as ordinarily built and operated, that it will eliminate a much greater proportion of bacteria, and that in appearance its effluent will be decidedly superior to that of the filter. This is a marked advantage under certain circumstances, but these facts alone should not be allowed to control in the adoption of a more expensive process when the accomplishments of the trickling filter answer all purposes.

Such a course would be like purchasing an article one does not want simply because it is cheap.

Complexity of Activated Sludge Process.—A disadvantage of the activated sludge process in the minds of many who have studied it is its apparent complexity and need for careful and skillful supervision. While it has been contended by some that this process is exceedingly simple, and one which can be operated by a workman of ordinary intelligence, the consensus of opinion appears to be to the contrary. The author's experience in operating several small experimental plants leads him to feel that of all processes of sewage treatment in practical use in this country to-day this is by far the most difficult to operate, and that it will require the skill of a well-trained engineer or chemist to ensure continued satisfactory results with it.

The Activated Sludge Treatment of Industrial Wastes.

Many of the problems of industrial wastes treatment are similar in character to those of the treatment of municipal sewage. Most of such wastes contain organic matter, which must be oxidised by bacterial action before they can properly be discharged into small watercourses, or into other waters where dilution is restricted.

Where wastes are free from chemicals inimical to bacterial life, the organic matter contained in them can be oxidised by the ordinary process of sewage treatment. The trickling filter has been repeatedly found to be capable of carrying on such oxidation.

During the past year investigations have been made under the writer's direction of the activated sludge process as a means of oxidising the organic matter in tannery, paper mill and woollen mill wastes. All of the tests have met with some degree of success. The tannery wastes appear to be particularly well adapted to this treatment.

At a sheepskin tannery, where the wastes are several times as strong as ordinary municipal sewage, a satisfactory effluent, entirely stable, free from suspended matter, and with very slight turbidity, was produced with the expenditure of 10 cub. ft. of air per gallon of wastes. The period of aeration was 12 hours, and in the winter the wastes were artificially heated to about 70 deg. F. to facilitate the tests. Whether or not it will be necessary always to heat the wastes during winter has not been determined, but it is not anticipated.

The woollen-mill wastes were very susceptible to the activated sludge treatment. A clear, stable effluent can be produced, but the quantity of air which will be necessary to achieve this result has not yet been determined.

Conclusions.—At the present time it appears that the Imhoff tank-trickling filter process is a less expensive means of oxidising the organic matter of sewage and industrial wastes than the activated sludge process, where oxidation alone is considered. If the areas of land required for isolation, the loss of head in the plant, the danger of objectionable odours and of the fly annoyance, and other disadvantages of the trickling-filter process are of marked importance in any specific case, the balance may be decidedly in favour of the activated sludge process, even in its present state of development.

The activated sludge process should receive, and is having, much study. There are many problems connected with it which may be solved in such a way as to put it in a much more favourable position. It is to be seriously hoped that investigations will go forward until the process is thoroughly perfected. In the meantime, also, further attention should be given to improvement in the design and operation of the older processes of sewage treatment.

Issue of French Import Licences in London.—With reference to the recent announcement as to the issue of licences for the importation into France of goods of British origin, the Board of Trade notify that the French Customs Office at Bank Buildings, Kingsway, London, W.C. 2, is now prepared to receive applications from exporters in this country for French import licences in respect of those classes of goods for which it has been arranged that licences shall be issued in this country instead of in France. Applications, which must be in the prescribed form, should be made direct to the French Customs Office in London, and must be supported by a certificate issued by a Chamber of Commerce certifying that the goods are the produce or manufacture of the United Kingdom. Full information regarding the procedure to be adopted may be obtained from the office above-mentioned or from the Commercial Department, Board of Trade, Gwydyr House, Whitehall, S.W. 1. A detailed notice will appear in the forthcoming issue of *The Board of Trade Journal*, and advance copies of this notice have been furnished to the Chambers of Commerce throughout the country.

Brazilian Zircon.—We read in *The Iron Age* that the American Consul-General reports to the Department of Commerce that Brazilian zircon appears to be becoming more and more a marketable product in the United States. An American company, he writes, is said to be offering it in Rio at 50 dols. to 60 dols. per ton. His report says : Zircon is used chiefly in the manufacture of refractory crucibles and for the refractory linings of furnaces. Silicate of zirconia, the mineral known as zircon, is found in small crystals mixed with monazite in the sands out of which the Brazilian monazite is washed. In the process of recovering monazite from these sands the zircon and the ilmenite (black oxide of titanium and iron) are separated. As the ilmenite has apparently no commercial value it is thrown away, but according to exporters, zircon can be marketed at 50 dols. a ton with a small profit, in spite of high freight rates. With the present electric separating machines it is practically impossible to remove all the monazite from the zircon, and a residium of 2 per cent. to 6 per cent. of monazite is bound, it appears, to remain with the zircon. This percentage, it is claimed, is irrecoverable, and has practically no value. It is stated that increasing quantities of zircon exports may be expected from Brazil, provided this article is not too heavily burdened with customs duties in the United States and is classified as zircon and not as monazite.

Wall Street, New York, and the Iron Market.—Every now and then, says *The Iron Trade Review*, Cleveland, Ohio, Wall Street essays to pass its judgment, according to its own standards, upon some phase or development of the iron and steel industry. Such a demonstration was given during the past week (August 5 to 12), when a report was spread broadcast that the Government had fixed upon 27.50 dols. as the price which it would pay for pig-iron. This was a figure below the cost of production, so the report ran and therefore revealed a most unfavourable state of affairs for the manufacturers. Iron and steel security values registered a severe swamp. Wall Street forgot, or did not want to recall, that only a few days before it had judged as gratifying the Government announcement that its purchases would allow fair and resonable profits to the iron and steel manufacturer. The truth is that the Government had bought several thousand tons of foundry iron to be split up among many producers ; that a price of 27.50 dols. does accompany the purchase, but only as an initial price which is subject to change, depending upon the cost determination of the Federal Trade Commission investigation, and that the producers and the Government are co-operating freely on a basis of mutual confidence in each other's fairness. There is no danger of the pig-iron maker being forced to accept orders below cost, and the Government's fixing of costs is to include a reasonable profit over production charges. All of which goes to show, adds our contemporary, that as a medium for accurate dissemination and interpretation of iron and steel news, Wall Street is about the last place in the world for the industry to go.